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MENTAL WORKLOAD MEASUREMENT FOR COMPETITVE VIDEO GAMES

By

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B.S., University of Louisville, 2016

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MENTAL WORKLOAD MEASUREMENT FOR COMPETITVE VIDEO GAMES

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ABSTRACT

The purpose of this study was to explore different ways to measure mental workload for competitive video games using two different techniques: heart rate variability (HRV) and the NASA Task Load Index (TLX). eSports is a rising form of a competitive sport as well as a source of entertainment for people all over the world. I write this in hopes to find efficient and verified ways to estimate mental workload. I also hope this work can pioneer the expansion of literature for the competitive gaming scene.

The study design is a single factor, within-subject design. The single factor was Game Difficulty. There were two levels of this factor: "Games without mental arithmetic secondary task" and "Games with mental arithmetic secondary task". A gaming team of four team members participated in five trials (i.e., the gaming team performed a game with each of the two levels a total of five times). Analysis of Variance (ANOVA) was used for the collection of statistical analysis of HVR as well as the NASA-TLX survey.

Analysis revealed that HRV percent change were not sensitive to mental workload change during competitive gaming and that the NASA TLX instrument was more sensitive to mental workload changes but not completely effective. This thesis experiment provides an important contribution to the little literature available in the field

of gaming; this study was an important first step for further research in effective mental workload measurement in gaming.

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I. INTRODUCTION

In today's world, mental-workload and human performance can often be overshadowed the physical side of human factors an ergonomics. Human factors and ergonomics is the practice and design of tools and technology for people within their physical and cognitive capabilities and limitations; anywhere from digital user interfaces, to mental capacity and mental workload. Research shows that mental workload can be recorded in many different ways. The methods later described in this paper are two different mental workload measurement methods that track mental workload in very different ways.

Mental workload assessment has been an ascending topic in the literature for quite some time. The goal behind many experiments was to test the application to see how high the user's mental workload was. This is usually tested in applications such as flight, healthcare, manufacturing, and many other applications when working under pressure. However, one application that has very little displayed in the literature in competitive gaming, also known as E-sports. E-Sports stands for *Electronic-Sports* which is defined as Multi player video games often played by professional gamers in competitive matches and viewed in large arenas or streamed online. In volume of numbers, E-sports competes with all athletic events. Just to put that into perspective, Major League Gaming (MLG), which is the largest video game league in the United States, reported 54 million viewer-hours via video stream in 2013. That is four times the amount of viewer hours for the NCAA march madness tournament that same year.

With that many viewers economically speaking, gaming has an enormous market for outside companies in ad sales. People watch and view people playing all sorts of

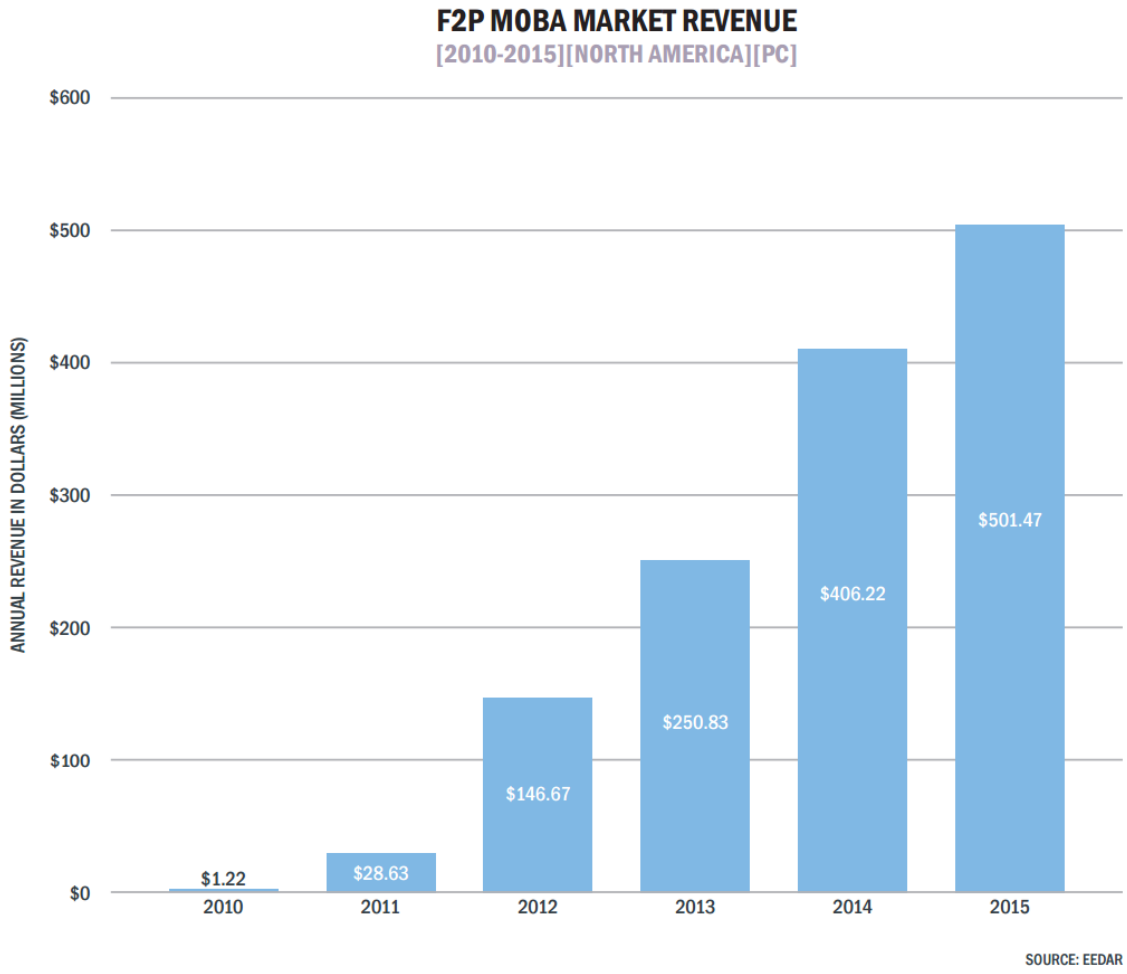
games all day long every day. Furthermore, exponential spike in viewership is observed during tournament game play. I believe that in the near future, E-sports will be included in our collegiate NCAA sports program. Universities such as Harvard, Stanford, and UCLA already have organized gaming organizations in which they create teams specific to the game played and compete with other colleges in the United States.

This could be a major development for the competitive scene of gaming. An abundance of money is getting put into these tournaments and LAN events, most of which go to the top 2-4 teams. The competition is going to keep getting bigger, organizations and teams are going to want proven strategy and methods to put their players in the best possible position to succeed. I believe that with further research in the human-computer interaction for gaming, specifically in human factors engineering, the competitive scene of these video games would have more of an understanding of how to train and prepare for these million dollar tournaments.

Of recent years the professional gaming industry, and specifically E-sports has dramatically risen in popularity. These games are starting to make their way into the college scene to be fully supported by the nations public and private university's and institutions. Games such as League of Legends, Smite, and Dota 2 all have a very competitive nature, and are generating a great deal of money. In august of 2015 the Dota 2 international tournament had a total prize pool over 20 million dollars.

In these tournaments, the players are recognized as athletes and put through many strenuous situations while playing. With that much money on the line, one wrong click could be the difference between 1 million dollars and zero money. With that being said, the mental stress they endure imaginably would be overwhelming to the average person.

FIGURE 1 – Multiplayer Online Board Arena (MOBA) Market Revenue chart



(EEDAR, 2015a)

Just in the Multiplayer Online Board Arena (MOBA) games, the annual revenue has increased from 1.22 million to 500 million over a 6 year span. With those type of stakes, its only safe to assume that the industry would continue to grow as awareness grows throughout the world. As the competition keeps getting bigger, organizations and teams are going to want proven strategy and methods to put their players in the best

possible position to succeed, including having an understanding of how to train and prepare for these million dollar tournaments.

To see if this was applicable I decided to do a survey about video games prior to settling on specific research questions. The goal of the survey was not to gain quantitative information for statistical analysis. Rather, the point of the survey was to gamers' understanding for what it means to be mentally fatigued, or putting yourself through mental strain. From that I derived my thesis questions, along with other new points of interest that came about. The most important question I believe was: 'Do you ever feel mentally or emotionally drained while playing?'. Many people indicated that they did not. When asked to explain, many answered along the lines of "playing video games after a while just becomes a natural reflex and I don't think hard when I am playing, my success comes from experience."

The purpose of this study is to increase awareness and understanding of mental workload measurement in regards to competitive gaming. With little to no research in the field of competitive gaming, this thesis provides a contribution to the literature in the field of mental workload. Some people think that once you do something for so long it becomes natural, and everything is just reflex. I conducted this study to counter the "I could do this in my sleep phenomenon". As an avid gamer, I thought it would be a unique study to use methods introduced in my Human Factors and Ergonomics class to perform a study in one of my own hobbies.

For my study, I selected two different mental workload measurements to help get a better understanding of what exactly gamers put themselves through during game play. With this study, it is very possible that some game developers would look into different

ways to either change the complexity of the games, or create situations to relieve stress for the wellbeing of their daily users. This could eventually become a more in-depth study for future research. I want this to be this study to spark other studies to better understand the mental side of human factors and ergonomics for computer gaming. We see the development in keyboards and other input devices used, headsets, and even monitors. All of these physical advantages put the user in a comfort zone. The goal is to create the same comfort zone with mental relief.

Thesis question: Is there a relationship between competitive gaming and high mental workload? What methods are best for measuring mental workload for competitive gaming? I used two different measurement tools to measure mental workload. They are heart rate variability and a subjective survey, the NASA Task Load Index (TLX) survey. Secondary task measurement (mental arithmetic) was used to artificially increase mental workload. This thesis investigated if one or both of the two types of mental workload measures (HRV and the NASA TLX) are sensitive to an increase in gaming mental workload, as imposed by a secondary task.

Hypothesis

1. HRV will have a statistically significant difference between games without secondary task and without secondary task.
2. The NASA-TLX overall score will have a statistically significant difference between games without secondary task and without secondary task.

For the purpose of this experiment used the MOBA game ‘League of Legends’. To refer to some of the functions within the games listed some common definitions that many gamers use.

- ***Mid-*** This is a player who is in a lane one on one most of the time trying to push to the enemy's tier 1 tower. They are often left to roam around the map and have a high impact on the game.
- ***Utility/solo-*** This person is to always play extra careful and their job is to gain as much experience as possible so that when the team fighting starts they can have an impact.
- ***Carry-*** This is the person who is supposed to deal the most damage by the end of the game. As well as securing the most kills. As role of importance in other sports this is your LeBron James, Kobe Bryant, or Tom Brady type of super star.
- ***Lane-*** A lane is an area that has three towers for each side and minions that come into the lane every 30 seconds. Champions go to one of three lanes to try and get an objective advantage to eventually get to the other teams' base.
- ***Map-*** This is the board that the users use and navigate around.
- ***KDA-*** Kill Death Assist ratio is just an in game stat that shows some level of in game performance
- ***Team fight-*** This is when multiple champions for both teams find each other on the map and use their abilities to try to take each other down within the game. (usually a 5v5 user interaction).

Conducting research in the area is more than just a personal interest for me. I understand the study of comparing multiple methods along with combining methods has be done before to calculate mental workload. However, what I hope to achieve is to open the realm of gaming to other research in the gaming industry. I believe this is something our future holds and will continue to grow maybe to the level of other sports today. With

that thought, it is imperative that people continue to take the idea of mental workload and run with it for gamers, athletes, and people of all ages. The master's thesis is one of the first to have a documented experiment on mental workload for a Multiplayer Online Board Arena styled game.

II. LITERATURE REVIEW

The following is a review of the literature and information relevant to competitive gaming and mental workload measurement. There is very little within the literature that displays a concentrated focus on competitive gaming. This study as a whole targets this gap in the literature for competitive gaming. Mental workload measures have been demonstrated in the literature over a variety of areas. This review explains some of the pros and cons of different mental workload measurement techniques, specifically variations of physiological, subjective, and primary vs. secondary task measures.

A. Physiological Measures

Physiological measurement tools have been used to assess mental workload with the assumption that one can correlate mental workload and physiological measurements (Tsang and Vidulich, 2006). Some prefer this style of measurement because continuous changes with the recordings are captured. Some common physiological measures are cardiovascular (e.g., heart rate variability and heart rate), ocular (e.g., pupil dilation, eye movement measures), and measure of brain activity (e.g., electroencephalographic measure). Physiological measures can be effective for detecting changing in mental workload using different statistical data analyses techniques, such as Analysis of Variance (ANOVA)

a. Electroencephalographic Measure

Electroencephalographic measurement is one of the newer tools to date for mental workload assessment. An electroencephalogram is measured by placing electrodes directly on the scalp surface. The nodes are there to output spectral power and then record

brain activity. Two of the major frequency bands that are correlated to changes in mental workload manipulation are the alpha (7 to 14 HZ) and theta (4 to 7 Hz), (Tsang and Vidulich, 2006).

Spectral power in the alpha band that arises in wide spread cortical areas is inversely related to the attentional resources allocated to a specific task, whereas theta spectral power recorded over the frontal cortex increases with increased task difficulty (Parasuraman and Caggiano, 2002). This method has shown to be sensitive to changes in task demands in real work settings (Wilson, 2002). As noted before, physiological measures have an advantage of being able to continuously record data. Using a measurement tool that uses electroencephalography can actually track fluctuation in mental workload. This would work extremely well task that have varying stages for completing the primary objective or goal.

b. Pupil Dilation

Pupil dilation is also used as a way to measure mental workload. Mental load can be characterized by physiological changes within the autonomous nervous system that have been associated with the investment of mental effort to deal with a task (Causse et al., 2010; Fairclough et al., 2005). For pupil changes the degree of response correlates with the workload of the task and holds true between the task and user (Murata and Iwase, 1998; Iqbal et al., 2004; Goldinger and Papesh, 2012; Murata et al., 2013). Tracking eye movement can also give detail to how much mental load a user is accessing. Again ocular tracking can be measured continuously and give data that one can use statistically analyze.

c. Heart Rate

Heart rate and heart rate variability are two also measures that fall under the physiological measurement techniques for mental workload measurement. This is executed by first measuring a user's resting heart rate before performing a task. After that heart rate is measured during the task. Continuous measurement of heart rate allows one to calculate heart rate variability. This measurement allows you to see when in time are there stages of a task with more or less mental capacity being used.

I choose to use heart rate variability as my physiological measurement for this experiment. This was the simplest way to have a continuous measurement of mental workload for the users while they are playing League of Legends. Electroencephalography would be a possibility as a tool for mental workload measurement during gaming; however, it was not a good choice for this experiment. The equipment is cost prohibitive and could be a distraction to achieving the primary task and goal. Also, pupil dilation and eye tracking could have been an effective measure. While playing competitive video games, one's eyes are fixated on one location for a sustained period of time. Although the ability to test each individual user's eye movement and pupil dilation would have been beneficial for the goals of this thesis, but I did not have the means acquire that type of technology. These methods are well validated in the literature, but they did not meet my direct needs for the purpose of this experiment. The simplicity and ease of continuously measuring heart rate seemed to be the best plan of action as one could measure heart rate without making too big of a change to the user's natural playing conditions or comfort level. I think that the Fitbit wrist heart rate monitor, which is what I used for this experiment, is easy enough to take off and put on. Also, the Fitbit is something many type of people can use with virtually no health and safety risk.

Real time detection of heart rate variability is essential to this experiment. Without this method of mental workload measurement, I would not have a true assessment of task difficulty at each point in time. Heart rate variability has a lot of meaning behind where it is generated from or what comes from having a high or low heart rate variability. For this experiment I am using heart rate variability to confirm a high mental workload by users playing league of legends.

There are two measures for confirming a high mental workload using heart rate in general. The first is what is explained in this article. How much of one's the heart rate varies over a specific time frame. Low variability suggest that the user is in fact going through high mental workload over that time period while doing a task (Hoover, Sing, Firshel-Brown, and Muth. 2012). However, if the heart rate has a lot of variance then that suggest that the task they are performing may not be all that strenuous of a task. This measure is used in many different practices such as fight, medical programs, even in athletics. Thus, this seemed as a go to measurement for measuring mental workload.

B. Subjective Measurements

Subjective measurements are measurements that are given either before or after a task has been performed. Some people believe that subjective ratings are maligned unfairly (Annet 2002a,b). Because within these measures its all about how the user interprets the actual survey or questionnaire. Users could look at a survey after working on an assembly line in a manufacturing plant and believe just because their job was difficult, so was there mental load. This is a common misconception when using subjective measurements. With that being said, there are many highly respected and

validated subjective measurements that are used a lot during the literature. Some of these measures are the Bedford Workload Scale, Cooper- Harper Rating Scale, NASA Task Load Index, and overall workload scale. All of these scales have been used in the literature and are well known amongst the scholars within human factors engineering and cognitive engineering.

a. Cooper-Harper Rating Scale

The Cooper-Harper Rating Scale is a decision tree based measurement (Roscoe, 1984). It was designed to track the adequacy of task, as well as track aircraft characteristics and measure how well pilots handle different aspects of an aircraft. The good thing about this subjective measurement tool is it pretty simple to implement and takes little to no prior training for use. However, this was mainly designed for pilot use and was not the best measure for me when searching for a highly validated subjective measurement tool.

b. Bedford Workload Scale

The Bedford workload scale was derived from the Cooper-Harper Scale; the process of the derivation came from trail and error with the help of test pilots at the royal Aircraft Establishment at Bedford, England (Roscoe, 1984). It kept the binary structure of the decision tree from the Cooper-Harper Scale. It also has the four- and ten-rank structures from the Cooper Harper Scale. Roscoe reported that the scale was welcoming to pilots because one did not have to always reference back to the decision tree. However,

this scale was designed for aviation tasks and therefore did not seem to be the best fit for my experiment.

c. Overall Workload Scale

The Overall Workload Scale is labeled as a bipolar Scale. What this means is on one end of the scale the rating is low and on the opposite end the rating is high. The Overall workload scale is designed to allow the participant to select one single workload rating. The scale goes from low to high on a horizontal line. The line is then divided up into 20 sections, the left end being the low end and the right end being the high end. One of the strengths of this scale it that it is really easy to use and simple to implement to almost any activity. The disadvantage of the scale is that its validity is questionable and it is less reliable than other subjective measures such as the NASA TLX measure (Vidulich and Tsang, 1987). The Overall Workload Scale just isn't used in many applications because other subjective workload scales such as the NASA TLX or the Cooper-Harper Rating scale have a larger line of research to support them. For this reason, I did not choose to use the Overall Workload Scale (Vidulich and Tsang, 1987).

d. NASA Task Load Index

The NASA TLX is the subjective measure I choose to use for this thesis experiment. This subjective measurement tool is a multi-dimensional workload rating scale that has two parts. One part is a binary scale system with six parts. The binary part works as a horizontal line with the low end being on the left and the high end being on the right; this line is broken up into 20 increments like the Overall Workload Scale. The

difference is there are six different measurement lines; Mental demand, Physical demand, Temporal demand, Performance, Effort, and Frustration level are all parts of the Rating sheet. Each of the bipolar measures are rated on a scale from 1-100 and the composite score for the six scales yields a total NASA TLX score. The other part is a series of further questions that give relative weighting of importance to each of the six measurements that were taken previously. However, I used unweighted TLX scores since the TLX weighting procedure has been found to be of limited benefit (Nygren, 1991).

This measure is sensitive to overall workload at it differs among tasks of various physical cognitive and physical demands (Hart and Staveland, 1987). With its sensitivity to workload in various applications it seemed to be the best fit for this experiment. This scale is easy to use because there are electronic versions created that can be displayed directly on the participant's computer monitor after completing a task. In contrast, mental workload scales were designed to be done with pen and paper. The NASA-TLX survey is displayed on each participant's computer screen, allowing them to easily take the survey after each game run of League of Legends.

C. Primary / Secondary Task Measure.

Primary and secondary task measures work hand in hand with each other. For this experiment, the primary task is playing League of Legends. This game is played on a very competitive level on various stages. The games are user vs. user-based so that created a challenge when designing the experiment. When measuring mental workload of a task, the difficulty of the task is typically manipulated to understand if the measures of mental workload are sensitive to changes in task difficulty. With a Multi Online Board

Arena game like League of Legends, all decisions and in-game tasks happen in real time and there is not a direct way to change the difficulty because it depends on how good the other users are. With this in mind, I decided to use a secondary task to change the difficulty for the primary task. Hoping that this would in fact allow each participant use more mental capacity to give better readings when playing under strenuous circumstances. The primary disadvantage to secondary task measurement is their intrusion into the primary task (Gawron, 2000). Some different types of secondary task measures that are validated in the literature are tracking secondary task, time estimation secondary task, and mental arithmetic secondary task (Gawron, 2000).

a. Tracking Secondary Task

Tracking is a validated secondary task that has been measured in many different applications. When using tracking secondary task, the user or participant must follow or track a visual stimulus which can be stationary or moving by positioning an error cursor on the stimulus using a continuous manual response device (Lysaght, et al., 1989, p. 232). A strength of tracking task is that it works directly with continuous mental workload measurement. The key to this is tracking requires nullifying an error between a desired and an actual location (Gawron, 2000). While this is a highly validated secondary task I did not think it would be best for my experiment because it would interfere too much with the primary gaming task. One must constantly look at the screen while playing League of Legends and use a tracking device that wasn't on the screen; this seemed like it would interfere too much from the primary gaming task for the thesis experiment. Also

the equipment needed to be able to do this may have been cost prohibitive for this project.

b. Time Estimation Secondary Task

Time estimation is a very simple and easy to use secondary task method. Participants are asked to produce a given time interval, generally 10 seconds, from the start of a sound (Gawron, 2000). Gawron states that measures for this task include the number of incomplete estimates and or the length of the time estimates given by the user. This technique has been demonstrated to be sensitive to changes in mental workload (Hart, 1978; Wierwille, Casali, Connor, and Rahimi, 1985). This is shown in an experiment ran by Bortolussi, Kantowitz, and Hart (1986); they found a significant increase in 10-second time production intervals between easy and difficult flight scenarios. This would have been the preferred secondary task measure for the thesis experiment; however, League of Legends has an in-game clock. Thus, the participants could use that in-game clock as an aide to estimating the time intervals, invalidating the secondary task measurement.

c. Mental Arithmetic

Mental Arithmetic secondary task is when subjects are asked to perform arithmetic operations such as addition, multiplication, subtraction, and division. The questions can be delivered either visually or aurally (Gawron, 2000). A major strength about this measure is the simplicity of being able to track good and poor performance as well as high and low mental workload. An example of this is an experiment by Green and

Flux (1997). They had aviation pilots add 3three to an aurally presented digit. In doing to they found that the performance time for the secondary task increased as the workload associated with the primary task increased. Gawron (2000) sates that it is important to compare the primary task performance with and without a secondary task to ensure that they are not sacrificing primary task performance to enhance secondary task performance.

I choose to use this method of secondary task measurement because it is simple to implement and track quantitative data. I needed to find a secondary task measure that could be done via voice so that way the subjects could use keep their eyes focused on the screen and both hands occupied on the mouse and keyboard. I believe that the Mental Arithmetic secondary task is something the participants can do without taking valuable resources from the primary task (i.e., visual, physical limitations, etc..). For the thesis experiment, T=this secondary task also works to artificially increase workload to compensate for the fact that there is no way to change the difficulty of the game League of Legends because of the player vs. player game style. This creates a good comparison between the subjective and physiological measures of the NASA-TLX and heart rate variability respectively.

D. Competitive Gaming

The scene of eSports and competitive gaming has been on the up and coming over the past few years. While there is little to no peer reviewed or scholarly literature on mental workload measurement for competitive gamers, there is some what some call "gray literature" about the industry as a whole. This literature is made up of statistical

data and technical reports written by people who specialize in the gaming industry. With this information the goal is for the reader to have a better understanding of the magnitude and impact the competitive gaming industry has today. eSports is defined as a term for the competition between players in a video game setting, eSports, Much like professional athletic sports, pit players of the highest skill levels against one another. Various organizations have constructed eSports tournaments where fans can either partake or watch professionals compete (EEDAR, 2015a). eSports is the genre that competitive video gaming falls under. This is where the top gamers compete against other players for cash prizes.

One of the things that may be a bit hard to grasp is the connection between mental load and video games. EEDAR classifies the strategy genre as those titles that place a premium on mental acuity during the planning and execution of gameplay (EEDAR, 2015a). The strategy genre is largely dominated by MOBAS, defined as a genre of gaming that typically involves players choosing a champion and then playing a team-based, 5v5 match with the ultimate goal of destroying an opponent's base; League of Legends and Dota 2 are examples (EEDAR, 2015b). This suggest that it is mentally taxing on an individual who plays games at a high level.

Below are some key dates to the origin of MOBAS. These games have become some of the front runners within eSports and were mainly generated from the game Defense of the Ancients (Dota).

History Overview of MOBA styled games:

2003- Defense of the Ancients first released as a mod map for Warcraft III

2009- League of Legends debuts as a F2P title

2010- Heroes of Newerth debuts as a retail title

2011- Heroes of Newerth goes F2P / Dota 2 unveiled and held The international tournament

2013- Dota2 officially released / Turbines Infinite crisis announced / League of legends LCS(League of Legends Championship Series) finals draw 32 million viewers

2014- Hi-Rez Studio game SMITE is released

(EEDAR, 2015a)

MOBA games have the highest percentage of eSports participation. MOBA games has done the best job of popularizing eSports through leagues and tournaments while also providing the best visual experience, resulting in a lifetime participation of over 75% across all game titles in that genre (EEDAR, 2015b). This resulted in eSports having a huge spectator scene. The question then becomes; if it is just people playing video games, why are so many people watching them? According to EEDAR just over 70% of eSports viewers that watch MOBA styled games watch because of the high skill level with which professionals play. So to them, watching these professionals play games like League of Legends and SMITE is entertaining as well as educational to the subject of gaming. During tournaments like DOTA 2's, the international streaming services such as YouTube, twitch.tv, and even ESPN capture the game play and broadcast it to large a large amount of viewers. This shows that the industry has tapped into a market that would continue to grow and be a source of entertainment such as NBA basketball or NFL football. About half of the MOBA viewers spend between 1-4 hours watching some sort of eSports while another 20% watch between 10-14 hours a week (EEDAR, 2015b).

III. Methods

This experiment was approved by the University of Louisville's Institutional Review Board (IRB). The design of this experiment involved subjective, physiological, and secondary task measurements of mental workload. The goal was to demonstrate as to whether or not these measures are sufficient enough for mental workload load measurement for competitive gamers. The subjective measurement is the NASA Task Load Index (TLX) survey; the physiological measurement is heart rate variability; and the secondary task index is mental arithmetic. The secondary task would ultimately be used to artificially increase mental workload of a constant task.

A. Subjects

Participants in my experiment consisted of a team of four volunteers from the University of Louisville's E-Sports club. All four subjects were male students. Due to the lack of diversity within the realm of gaming, it was not feasible to have an equal number of male and female participants. The demographics of people who play these free to play games, including League of Legends, are 28% female and 72% male (EEDAR, 2015a). This demographic supports my experiment of having four male participants. The goal of selecting people for the study was to reflect the current competitive scene for gaming, in doing so a team for a Multi Online Board Area styles game generally consist of all males.

All students were 18 years of age. Each subject has at least two years of non casual gaming experience to help replicate the competitive nature of professional gamers. Each participant attended two days of experimental data collection. I recruited my subjects by giving a brief presentation on my vison and ideals on where competitive

gaming is going. I found an experienced group of players in the cardinal E-sports club at the university of Louisville who actually competed in a local tournament and came in 3rd place out of 13 teams. I gave each participant the option to leave at any time and not be a part of the study.

B. Pilot Subjects

I choose to run a sample test with all my equipment with myself and a pilot subject to make sure the heart rate monitor was applicable. I ran two iterations each to help simulate how the actual experiment would go. We played the MOBA game known as SMITE. This game is not the same as game of League of Legends; however, it is the same style and would have the same common goal. Both the pilot participant and myself had multiple years of experience in gaming and have the competitive nature to replicate the same environment the test participants would experience.

TABLE I

FIT BIT AVERAGE HEART RATE TEST GAMES

	Pilot Subject 1	Pilot Subject 2
1	66	83
2	73	82
3	65	77

After conducting the pilot test to see if the Fit Bit would be consistent enough to measure the averages, I confirmed I could use this device to calculate the percent change in heart rate variability for my actual experiment.

C. Experimental Design

The experimental design was a single-factor within-subject design. This is because my only factor, or independent variable, is Gaming Run with two levels. A secondary task measure was used to artificially increase mental workload while the users are playing the game. The two levels of this factor are *"Not Given"* and *"Given" (secondary task)*. Each of the four participants played the game five time for both levels.

D. Independent Variables

My independent variable (Gaming Run) involves a secondary task to increase workload during gaming. These two levels of the independent variable were listed as the secondary task as *"Not Given"* or *"Given"*. The secondary task was delivered via audio sounds through a headset. Using the program skype, I asked a series of math questions throughout the game to each user all at the same time. Participants were not be able to hear each other's answers as each were muted to everyone except me. This way there was no bias response from what how participants responded.

E. Dependent Variables

The dependent variables were heart rate variability and NASA-TLX survey. I used a Fitbit heart rate (HR) wrist monitor to continuously measure heart rate while

playing League of Legends. Research shows that a decrease in heart rate variability suggest that there is actually an increase in mental workload. This was a key component in justifying that the added secondary task would increase the difficulty of the primary task, therefore increasing the participants' overall mental workload. The NASA-TLX survey is a subjective measure that has been validated through many different studies. This survey also gave a different approach to analyze a gamer's mental strain while playing competitive video games.

For a task such as playing video games or anything where one is competing against another party, it is important to also look into performance measure as well. Within the game League of Legends, the team one is on can win or lose. This was one of the performance measures for each of the games played. Another gaming performance measure is kill death assist ratio. This ratio is recorded each after each game and records how often each participant achieved a kill (a success) died (a failure) or achieved an assist on a kill (a success). This measurement of kill death assist ratio is also referred to as KDA. KDA and W/L statistics was observed as I changed the experiment from no mental mathematic secondary task, to adding that variable in the experiment and artificially increasing mental workload.

F. Facilities Equipment and Materials

The experiment was conducted on the campus of University of Louisville. It took place over a course of two days and each session lasted approximately 5 hours. The

building and room used was J.B. Speed room 100. For this experiment, there was no materials that needed to be used by the participants.

The Equipment used was:

- 4 heart rate monitors (one for each participant)
- Desk space for four individual gamers
- Four computers with League of Legends downloaded on it as well as the NASA-TLX survey.
- Headset with microphone

The heart rate monitor as explained before was a Fitbit HR monitor. The reason for choosing this as the heart rate monitor of choice was because it is easily accessible and can be used with very little discomfort. Also it can continuously measure the participants heart rate while performing their primary task.

In order to play computer games there needed to be adequate space to use both a mouse and keyboard simultaneously. Therefore, four feet were allotted in between each player to allow for comfort and free range of motion for each participant. Each participant had their own computers with the game League of Legends already installed on them. I was responsible for uploading the files for the NASA-TLX survey onto each computer so that way after each game each participant was able to take the survey on their computer.

G. Procedure

Pre-experimental procedure: A day prior to meeting with the participants I sent them a reminder that the next day the experiment would take place. In this message the

participants were sent a list of items to bring, location, and expected time to start and end the experiment. I also asked the participants to arrive 15 min prior to the start time to try and work out any unforeseen technical difficulties. Participants first read and signed the consent document. After that, each game station was set up to make sure that they were comfortable in their seats. Each participant's resting heart rate was taken before they began to play their game for later data analysis.

*Experimental procedur*e: The participants were instructed each participant to play as they normally would while playing League of Legends. I then made sure all participants were recording their heart rate before they began to search for a match. This allowed me to record additional resting heart rate data in the same reading for the actual game run. After the first game was played, I asked all of the participants to stop their heart rate monitor and move forward with the subjective measurement. This was the NASA TLX survey that displayed on each screen at the conclusion of the game run. I then explained what each of the six questions were referring to and asked if they had any questions regarding the survey. This process was completed five times, once after each game.

On day two I again recorded the resting heart rate of each participant before the start of the experiment. I then set up a voice channel on Skype to be able to communicate with each participant via headset. Within the voice chat I muted each of the participants from hearing each other. This way the participants could only hear my voice, and they were not be able to give a biased answer based on what someone else said. I preformed this test over a course of five games. After each game the participants completed the subjective measurement of mental workload and via the NASA-TLX survey.

H. Conditions

There were two conditions listed for this experiment. One was being able to play League of Legends with no distraction. This was to get a true rating of how the average gamer does while playing a competitive video game. This allowed the team to be able to play free of stress and communicate with each other with no outside pressure.

The second condition was playing while also performing a secondary task. This secondary task measure involved mental arithmetic while also playing League of Legends. This ultimately put stress on the participants while they were playing. This could help replicate the environment of a high stress game. MOBA-styled games often have international tournaments that teams compete in. The teams sometimes compete for millions of dollars and play in front of a large crowd. So the stress level at these LAN events can be extremely high.

I. Risk factors

There were no foreseen risk factors while playing League of Legends. The participants were given a five minute break between each game so that fatigue did not affect their game play.

J. Post-test questionnaire

After each game played the subjects received the NASA-TLX survey which measures mental workload and mental stress.

IV. RESULTS

The following is a quantitative analysis of the results derived from the experiment. This experimental design was a single factor completely within subjects. Each subject ran through the experiment five times without a secondary task and with a secondary task. The following data was taken from a One-Way ANOVA analysis with the secondary task measure split into two levels, Level 1 is when there was no secondary task present, and Level 2 is when the secondary task was given to the participants.

TABLE II

DATA FROM AN ANOVA TO TEST A SIGNIFICANT DIFFERENCE FOR TOTAL WORKLOAD RATING FROM THE NASA TASK LOAD INDEX SURVEY.

Total Workload vs. Secondary Task

Source of Variance	DF	Adj SS	Adj MS	F-Value	P value
Secondary task	1	666.9	666.9	3.5	0.069
Error	38	7242.2	190.6		
Total	39	7909.1			

* indicates significant difference at $p<0.05$

TABLE III

MEANS FROM THE ANOVA TABLE AND CONFIDENCE INTERVALS GIVEN.

Secondary Task	N	Mean	St Dev	95% CI
1	20	52.46	15.09	(46.21, 58.71)
2	20	60.63	12.39	(54.38, 66.87)

Using an alpha level of 0.05, the Results in Tables 1 and 2 show that the participants playing League of Legends did not rate the NASA-TLX survey different enough to show a significant difference between the two factors of playing with and without a secondary task. However, having a *p* value of 0.069 shown in Table 1 suggests a trend toward significance between the two. Table 2 shows that the mean scores for games played at each level were different by about eight points.

FIGURE 2 - COMPARISON OF TOTAL WORKLOAD SCORE AND SECONDARY TASK LEVELS.

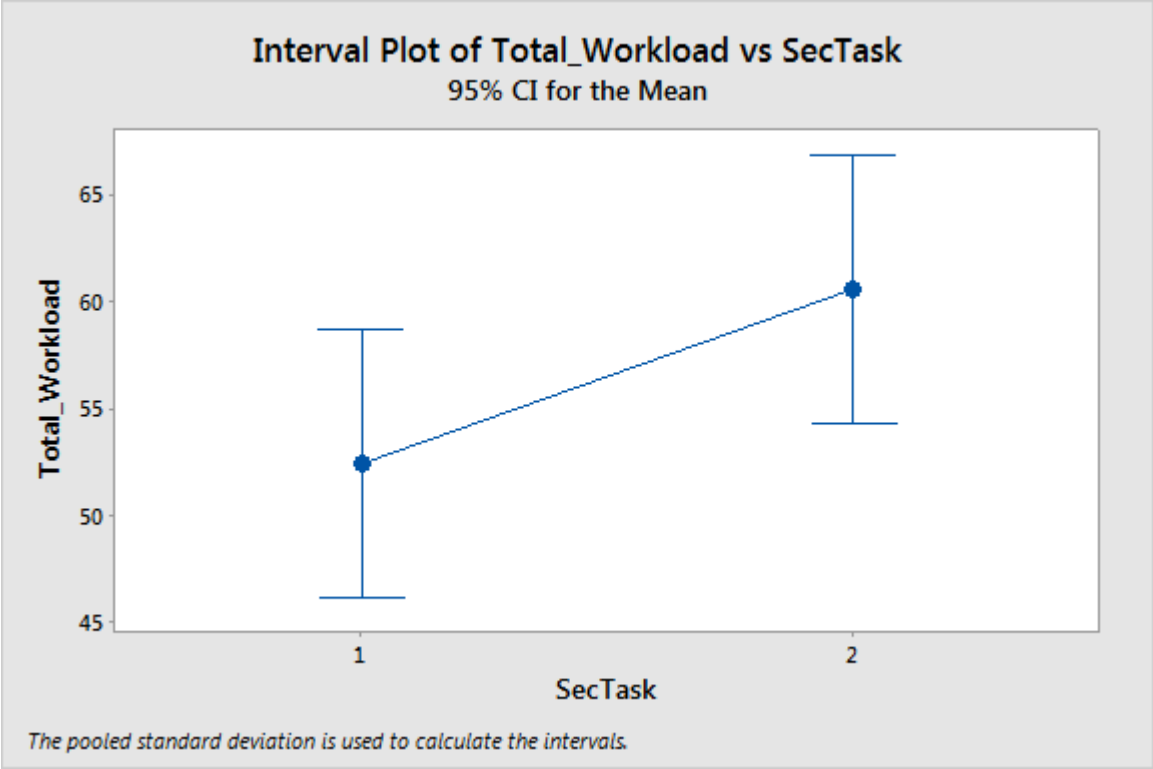


TABLE IV

DATA FROM AN ANOVA TO TEST A SIGNIFICANT DIFFERENCE FOR MENTAL DEMAND RATING FROM THE NASA TASK LOAD INDEX SURVEY.

Mental Demand vs. Secondary Task

Source of Variance	DF	Adj SS	Adj MS	F-Value	P value
Secondary task	1	1322	1132.5	4.75	*0.036
Error	38	10575	278.3		
Total	39	11898			

* indicates significant difference at $p<0.05$

TABLE V

MEANS FROM THE ANOVA TABLE AND CONFIDENCE INTERVALS GIVEN.

Secondary Task	N	Mean	St Dev	95% CI
1	20	57	17.8	(49.45, 64.55)
2	20	68.5	15.48	(60.95, 76.05)

Out of the six subscales in the NASA Task Load Index Scale, Mental Demand was the only one to have a significant difference between levels 1 and 2 of the secondary task. Subjects that received the mental arithmetic (secondary task) rated their Mental Workload as significantly higher during the gaming runs with the secondary task present ($p<0.05$).

The means for Mental Demand differed by 11.5 points on the NASA-TLX survey. This supports that there was indeed a significant difference between the two levels of secondary task shown in Table 3.

FIGURE 3 - COMPARISON OF MENTAL DEMAND SCORE AND SECONDARY TASK LEVELS.

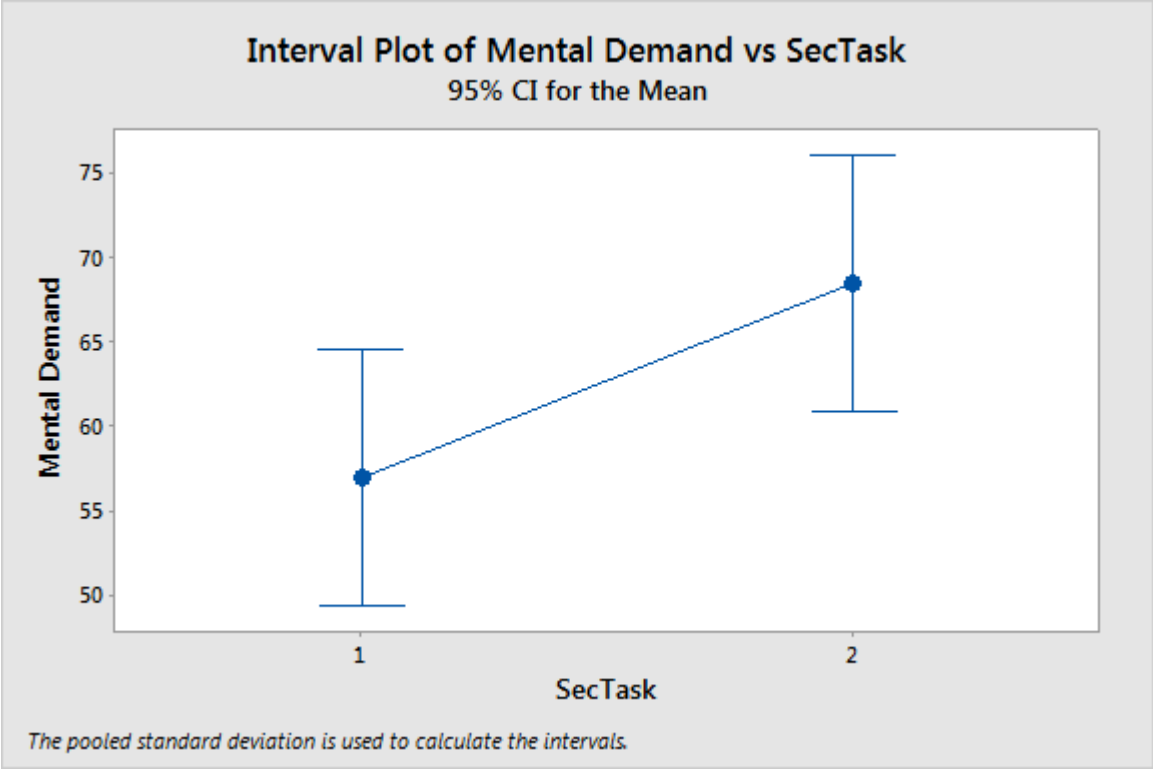


TABLE VI

DATA FROM AN ANOVA TO TEST A SIGNIFICANT DIFFERENCE FOR THE PHYSICAL DEMAND RATING FROM THE NASA TASK LOAD INDEX SURVEY.

Physical Demand vs. Secondary Task

Source of Variance	DF	Adj SS	Adj MS	F-Value	P value
Secondary task	1	0.6	0.625	0	0.969
Error	8	15343.8	403.783		
Total	39	15344.4			

* indicates significant difference at $p<0.05$

TABLE VII

MEANS FROM THE ANOVA TABLE AND CONFIDENCE INTERVALS GIVEN.

Secondary Task	N	Mean	St Dev	95% CI
1	20	37	20.99	(27.90, 46.10)
2	20	37.25	19.16	(28.15, 46.35)

There were no significant results for Physical demand (p>0.05)

FIGURE 4 - COMPARISON OF PHYSICAL DEMAND SCORE AND SECONDARY TASK LEVELS.

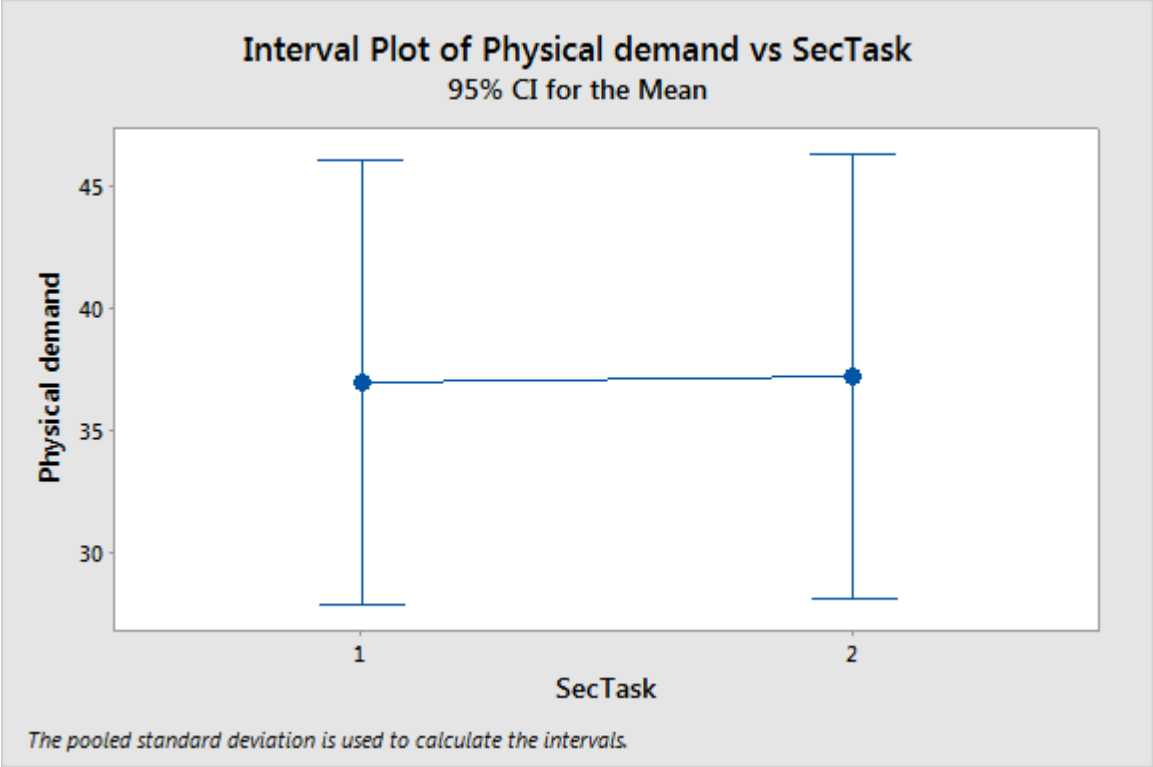


TABLE VIII

DATA FROM AN ANOVA TO TEST A SIGNIFICANT DIFFERENCE FOR THE TEMPORAL DEMAND RATING FROM THE NASA TASK LOAD INDEX SURVEY.

Temporal Demand vs. Secondary Task

Source of Variance	DF	Adj SS	Adj MS	F-Value	P value
Secondary task	1	1756	1755.6	3.95	0.054
Error	38	16904	444.8		
Total	39	18659			

* indicates significant difference at $p<0.05$

There were no significant results for Temporal Demand ($p>0.05$). However the p value was very close to 0.05 suggesting that there indeed was a difference just not a statistically significant one with 95% confidence.

TABLE IX.

MEANS FROM THE ANOVA TABLE AND CONFIDENCE INTERVALS GIVEN.

Secondary Task	N	Mean	St Dev	95% CI
1	20	54	21.31	(44.45, 63.55)
2	20	67.25	20.87	(57.70, 76.80)

FIGURE 5 - GRAPH DISPLAYING THE INTERVALS FOR THE COMPARISON OF TEMPORAL DEMAND SCORE AND SECONDARY TASK LEVELS.

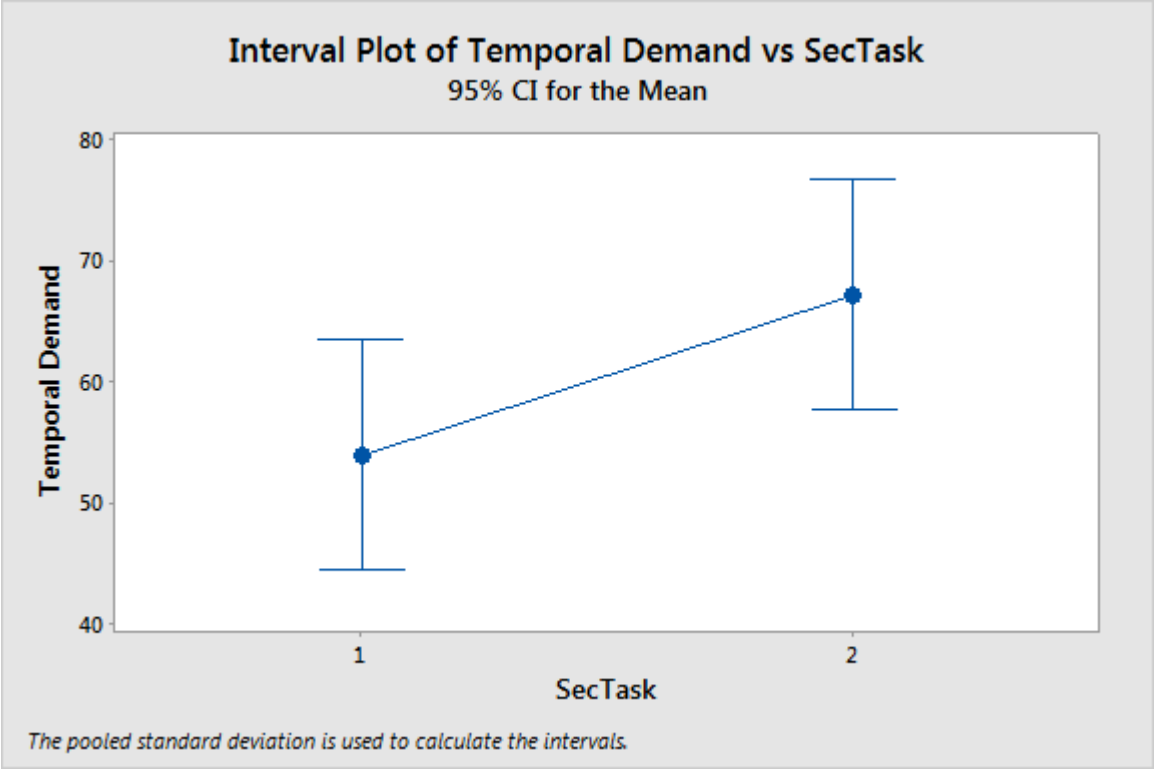


TABLE X

DATA FROM AN ANOVA TO TEST A SIGNIFICANT DIFFERENCE FOR THE PERFORMANCE RATING FROM THE NASA TASK LOAD INDEX SURVEY.

Performance vs. Secondary Task

Source of Variance	DF	Adj SS	Adj MS	F-Value	P value
Secondary task	1	30.6	30.62	0.07	0.8
Error	38	17838.7	469.44		
Total	39	17869.4			

* indicates significant difference at $p<0.05$

TABLE XI

MEANS FROM THE ANOVA TABLE AND CONFIDENCE INTERVALS GIVEN.

Secondary Task	N	Mean	St Dev	95% CI
1	20	56.25	22.59	(46.44, 66.06)
2	20	54.5	20.7	(44.69, 64.31)

There were no significant results for Performance (p>0.05).

FIGURE 6 - GRAPH DISPLAYING THE INTERVALS FOR THE COMPARISON OF PERFORMANCE SCORE AND SECONDARY TASK LEVELS.

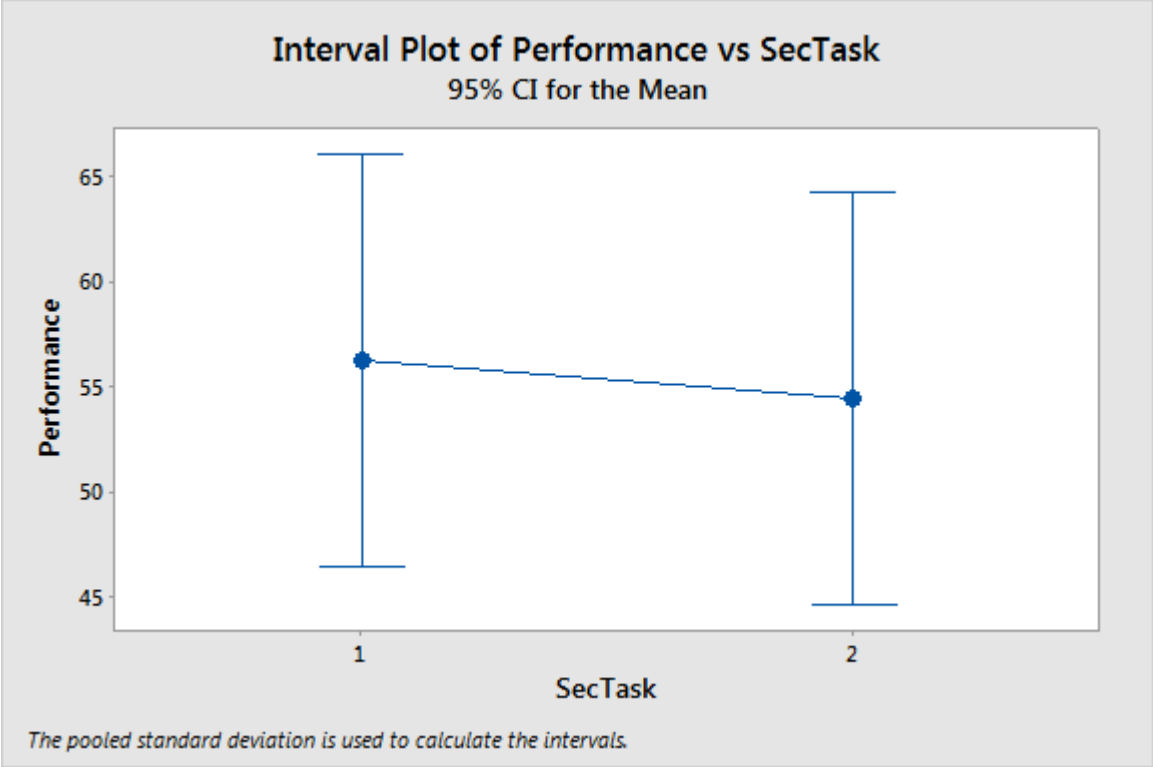


Table XI

DATA FROM AN ANOVA TO TEST A SIGNIFICANT DIFFERENCE FOR THE EFFORT RATING FROM THE NASA TASK LOAD INDEX SURVEY.

Effort vs. Secondary Task

Source of Variance	DF	Adj SS	Adj MS	F-Value	P value
Secondary task	1	902.5	902.5	2.17	0.149
Error	38	15807	416		
Total	39	16710			

* indicates significant difference at $p<0.05$

TABLE XII

MEANS FROM THE ANOVA TABLE AND CONFIDENCE INTERVALS GIVEN.

Secondary

Task	N	Mean	St Dev	95% CI
1	20	59.25	23.91	(50.02, 68.48)
2	20	68.25	16.13	(59.52, 77.98)

There were no significant results for Performance ($p>0.05$).

FIGURE 7 - COMPARISON OF EFFORT SCORE AND SECONDARY TASK LEVELS.

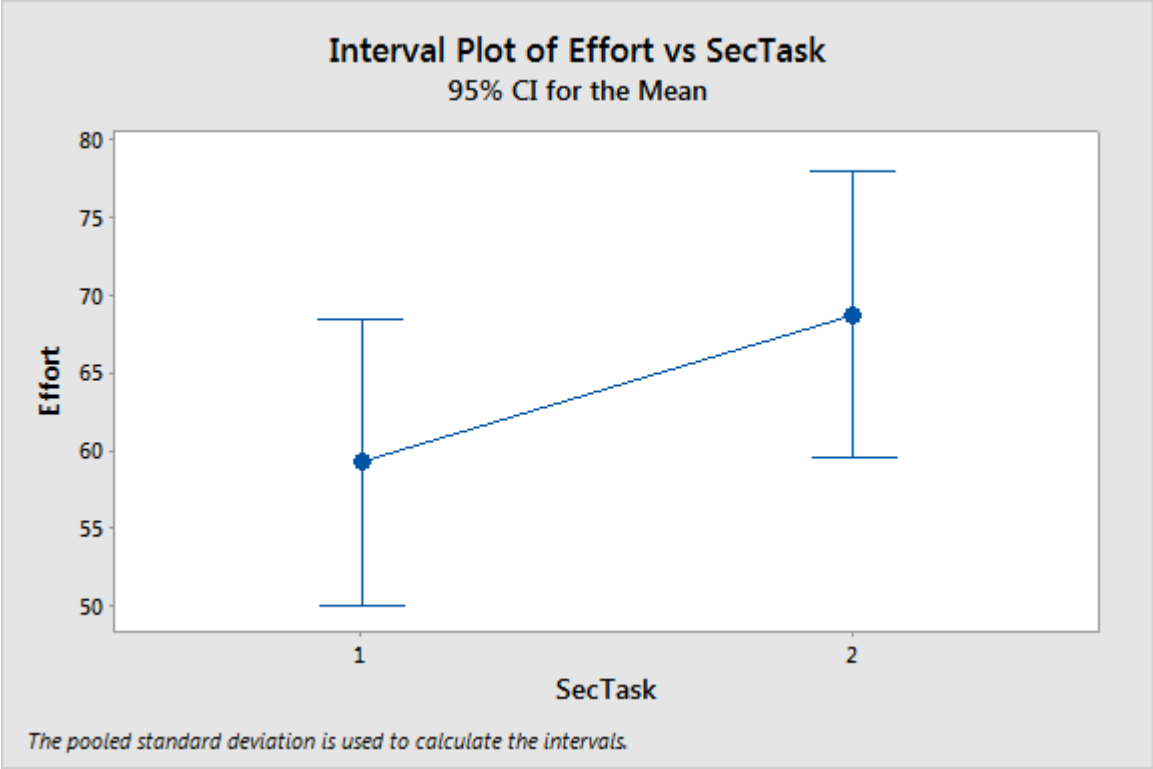


TABLE XIII

DATA FROM AN ANOVA TO TEST A SIGNIFICANT DIFFERENCE FOR FRUSTRATION RATING FROM THE NASA TASK LOAD INDEX SURVEY.

Frustration vs. Secondary Task

Source of Variance	DF	Adj SS	Adj MS	F-Value	P value
Secondary task	1	2641	2640.6	3.39	0.073
Error	38	29619	779.4		
Total	39	32259			

* indicates significant difference at $p<0.05$

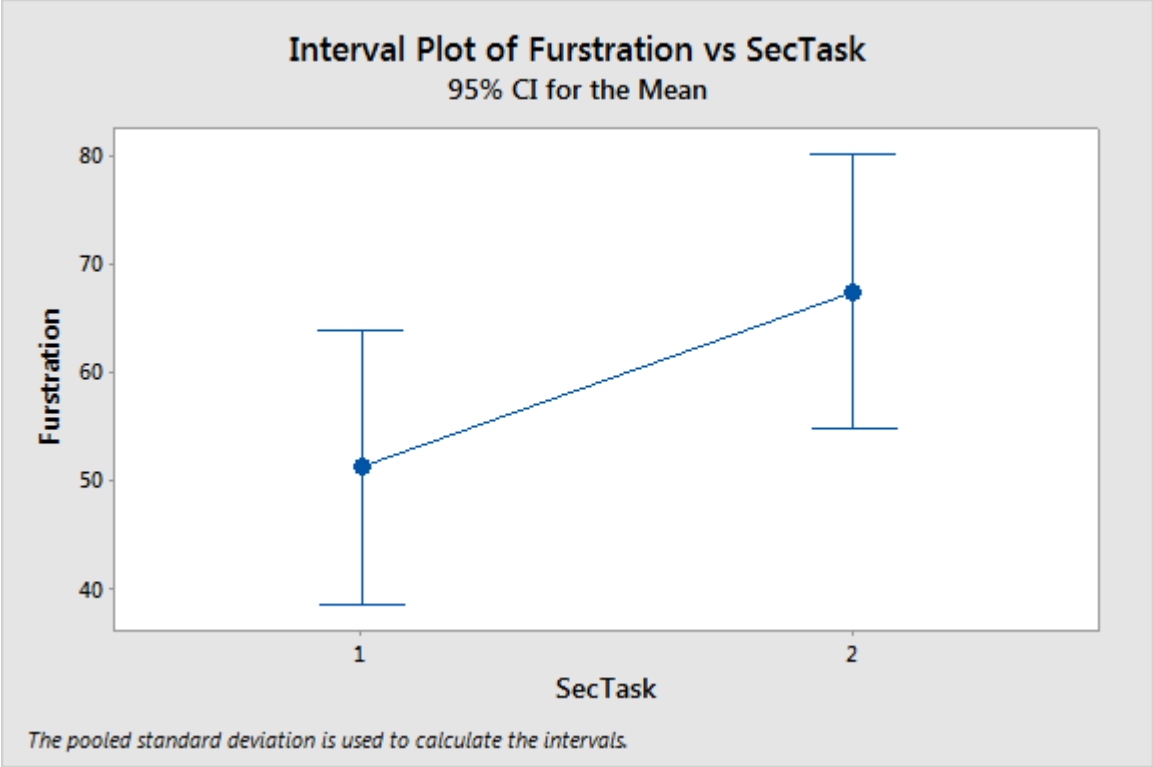
TABLE XIV

MEANS FROM THE ANOVA TABLE AND CONFIDENCE INTERVALS GIVEN.

Secondary Task	N	Mean	St Dev	95% CI
1	20	51.25	30.39	(38.61, 63.89)
2	20	67.5	25.21	(54.86, 80.14)

There were no significant results for Frustration (p>0.05).

FIGURE 8 - COMPARISON OF FRUSTRATION SCORE AND SECONDARY TASK LEVELS.



Secondary Task Results

FIGURE 9 - SHOWS THE RESULTS FROM SUCCESSES DURING THE SECONDARY TASK. SEE APPENDICES FOR FULL SPREAD SHEET.

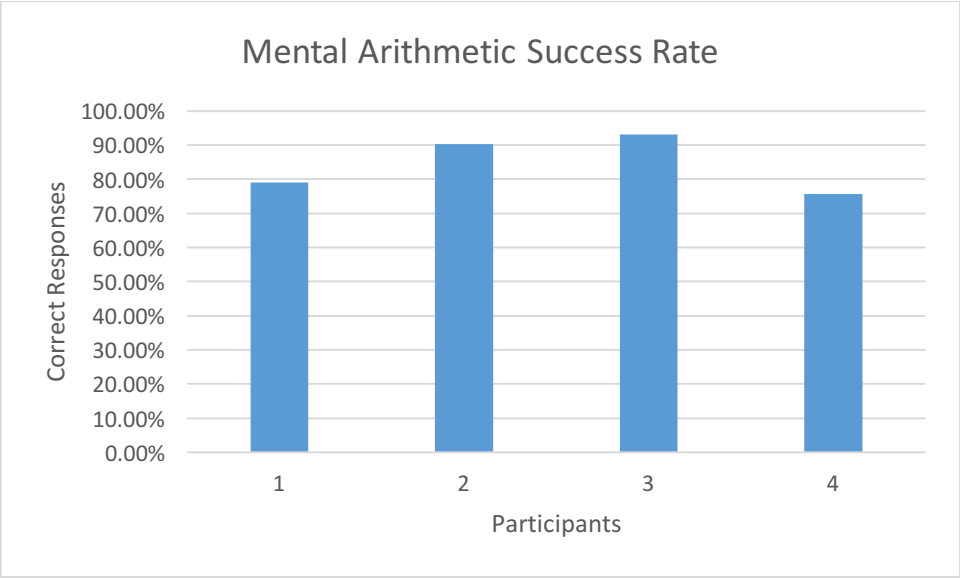


TABLE XV

DATA FROM AN ANOVA TO TEST A SIGNIFICANT DIFFERENCE FOR THE HRV FROM THE NASA TASK LOAD INDEX SURVEY.

HRV vs. Secondary Task

Source of Variance	DF	Adj SS	Adj MS	F-Value	P value
Secondary task	1	126.5	126.49	2.18	0.148
Error	38	2200.7	57.91		
Total	39	2327.2			

* indicates significant difference at $p<0.05$

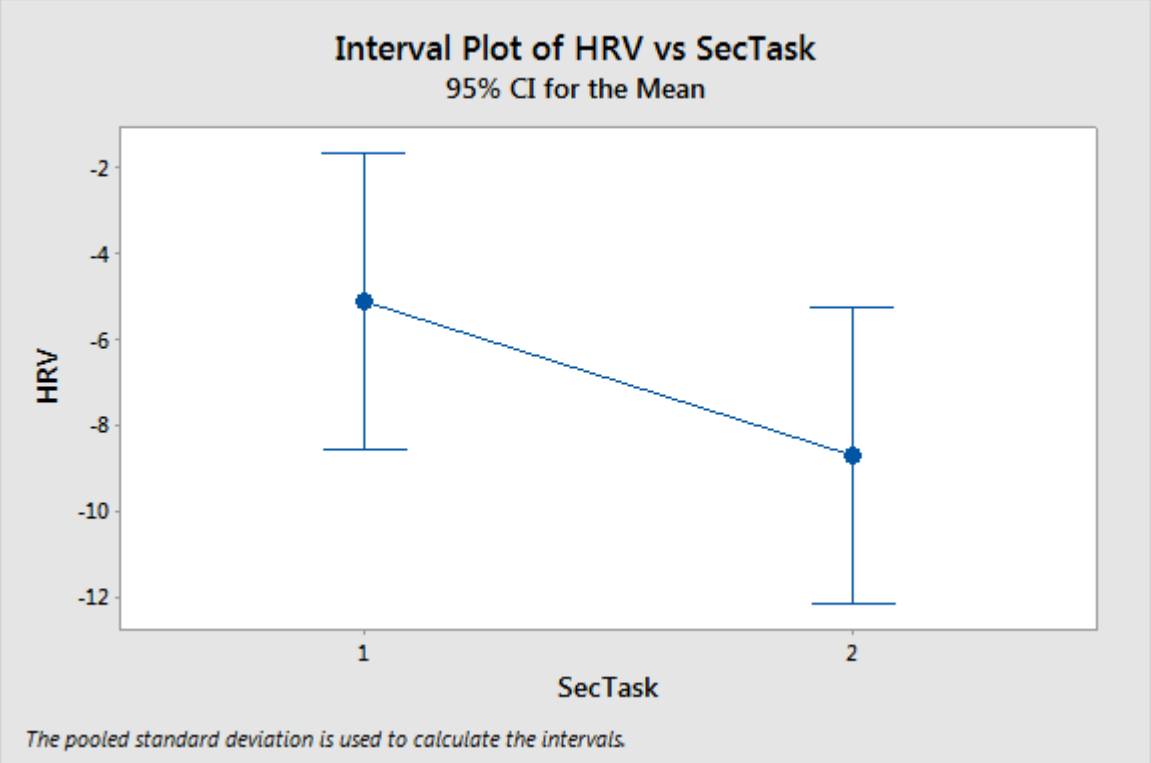
TABLE XVI

MEANS FROM THE ANOVA TABLE AND CONFIDENCE INTERVALS GIVEN.

Secondary Task	N	Mean	St Dev	95% CI
1	20	-5.12	8.51	(-8.56, -1.67_
2	20	-8.68	6.58	(-12.12, -5.23)

There were no significant results for HRV (p>0.05).

FIGURE 10 - COMPARISON OF HRV AND SECONDARY TASK LEVELS.



V. CONCLUSION

A. Summary

Validity of Hypotheses

1. The NASA-TLX overall score will show a significant change in mental workload between the different levels of gaming difficulty.
2. HRV based on percent change will show a significant change in mental workload between the different levels of gaming difficulty.

The first hypothesis was partially supported. While the overall TLX workload was not found to be significant at a 0.05 level of significance (p=0.069), the Mental Workload subscale was statistically significant (p=0.036) and other subscales approached significance: Temporal Demand (p=0.054) and Frustration (p=0.073).

The second hypothesis was not supported. HRV seemed to predict a relative change to mental workload for the participants between conditions; however, the difference was not found to be significant with an ANOVA (p>.0.05).

With this find I believe that there is still many other things done in this experiment that can indeed show a significant difference in mental workload. So as described in Chapter 3, the HRV was calculated as a percent change between resting heart rate and task heart rate to normalize the data for each user. However, I do believe that other forms of heart rate variability could in fact support a significant change in mental workload. One other variation of heart rate variability is from standard deviation.

Research shows that having a small standard deviation between continuous heart rate points shows high mental workload.

NASA-TLX instrument for the Mental Demand subscale was sensitive to changes to mental workload between the two gaming conditions; however, the overall score and other subscales did not seem to be completely sensitive to changes in workload. One reason the overall workload score did not show a significant difference is the actual task. Physical demand was always going to be low because everything on the computer is a pretty consistent physical task. And since it was a video game the participant's effort was always going to be high. It's a competitive game and it only made sense for them to compete to the best of their ability. However, their effort did vary at times, they believed that some of the games were a lot easier than others. Nevertheless, I believe the NASA TLX is a promising instrument for mental workload measurement for gaming.

Overall the experiment was executed successfully as planned. The transition from playing League of Legends with and without a secondary task present was very smooth. There was not much bias between the gamers as they were all fairly close in skill level. I do believe that they in fact did go through significant change in mental workload between the games with and without the secondary task; however, two mental workload measures I chose to test in this experiment may not be completely effective in measuring mental workload differences. Each of the four participants all completed each game in full and were able to produce quality data to analyze. At the end though I came to conclusion HRV percent change were not sensitive to mental workload change during competitive gaming and that the NASA TLX instrument was more sensitive to mental workload changes but not completely effective.

B. Future Research

It may be possible that the NASA TLX and HRV may have been more sensitive to detect workload differences with a greater number of participants and/or gaming trials; therefore, future research could replicate this experiment with a greater number of participants and/or gaming trials. Also, there are dozens of mental workload measures available; future research should test some of these other measures to see if they may be more suitable for mental workload measurement in competitive gaming.

An interesting observation was any time the team did not win a game, their performance was fairly low. This was an interesting point to take note on; even though some of games they won some individuals rated their performance as low. However, there was not a significant difference between any of these measures on the NASA-TLX survey.

The mental demand sub category was the only category that showed a significant difference between the two levels of difficulty. This made sense and was well documented in the experiment. When the participants did not have a secondary task measure in place they all thought that the games were some what challenging. But with mental arithmetic added as a constant thing the mental demand scores were a lot higher.

Even though only my first hypothesis was partially supported, there are many take a ways from the experiment. One item spoken about in conversation with the participants was the order of the different levels. Many of them would have rather played with the secondary task first because they felt that they would have played better after having those conditions imposed on them. This was a very eye opening concept to me because of the possibilities it opened me up to. This essentially was the idea of a type of training

program or mental exercise for competitive gamers. As of now the only known way to get better at these type of games is to just keep playing, and watch the replays of your own games to learn from your mistakes. If there was such a proven method to force the gamers to play at such a mental capacity or condition to increase, there situational awareness that would be of great interest for the industry. I believe that taking this method of applying a secondary task to gamers could be quite beneficial as a training regime to essentially condition the gamer to think faster and more effectively. It is important during these games to make decisions instantly and react to other player movements on the fly. If there was a way to condition gamers to be able to raise their situational awareness in terms of the in game strategy, I think that could be a major break through for the industry.

Doing this experiment taught me a lot about what it takes to put together a solid research experiment. I would say that there are many things to explore when it comes to gaming and human factors engineering. I realize this experiment was a simple experiment but I do believe that it could lead to something more refined and detailed to not only enhance mental workload measurement for gamers, but the overall user experience as well. This thesis experiment provides an important contribution to the little literature available in the field of gaming; this study was an important first step for further research in effective mental workload measurement in gaming.

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APPENDIX I: IRB Outcome Letter

The Internal Review Board of the University of Louisville approved the experiment on April 1st, 20016. The Full Letter is Disclosed on the Following Pages.

UNIVERSITY OF LOUISVILLE

Human Subjects Protection Program Office
MedCenter One – Suite 200
501 E. Broadway
Louisville, KY 40202-1798
Office: 502.852.5188 Fax: 502.852.2164

DATE: April 01, 2016

TO: Jason J Saleem, PhD

FROM: The University of Louisville Institutional Review Board

IRB NUMBER: 16.0130

STUDY TITLE: Mental Workload Measurement for Competitive Video Games

REFERENCE #: 516780

IRB STAFF CONTACT: Name: Jacqueline S. Powell, CIP
Phone: 852-4101
Email: jspowe01@Louisville.edu

This study was reviewed on 04/01/2016 by the Chair of the Institutional Review Board and approved through the Expedited Review Procedure, according to 45 CFR 46.110(b), since this study falls under Category 7: Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies

The following items have been approved:

Submission Components			
NASA Task Load Index (TLX)	Version 1.0	03/16/2016	Approved
Protocol	Version 1.0	03/16/2016	Approved
Informed Consent	Version 1.0	03/21/2016	Approved

This study now has final IRB approval from 04/01/2016 through 03/31/2017.

Privacy & Encryption Statement

The University of Louisville's Privacy and Encryption Policy requires such information as identifiable medical and health records: credit card, bank account and other personal financial information; social security numbers; proprietary research data; dates of birth (when combined with name, address and/or phone numbers) to be encrypted. For additional information: http://security.louisville.edu/PolStds/ISO/PS018.htm.

Implementation of Changes to Previously Approved Research

Prior to the implementation of any changes in the approved research, the investigator will submit any modifications to the IRB and await approval before implementing the changes, unless the change is being made to ensure the safety and welfare of the subjects enrolled in the research. If such occurs, a Protocol Deviation/Violation should be submitted within five days of the occurrence indicating what safety measures were taken, along with an amendment to revise the protocol.

Unanticipated Problems Involving Risks to Subjects or Others (UPIRTSOs)

In general, these may include any incident, experience, or outcome, which has been associated with an unexpected event(s), related or possibly related to participation in the research, and suggests that the research places subjects or others at a greater risk of harm than was previously known or suspected. UPIRTSOs may or may not require suspension of the research. Each incident is evaluated on a case by case basis to make this determination. The IRB may require remedial action or education as deemed necessary for the investigator or any other key personnel. The investigator is responsible for reporting UPIRTSOs to the IRB within 5 working days. Use the UPIRTSO form located within the iRIS system to report any UPIRTSOs.

Continuation Review Requirements

You are responsible for submitting a continuation review 30 days prior to the expiration date of your research study. Investigators who allow their study approval to expire have committed significant non-compliance with federal regulations. Such lapses may require reporting to federal agencies, a program audit by compliance auditors to ensure that subjects were not enrolled during the expired period, and may lead to findings of serious and continuing non-compliance if expiration were to occur a second time.

The committee will be advised of this action at a regularly scheduled meeting.

If you have any questions, please contact the HSPPO at (502) 852-5188 or hsppofc@louisville.edu

Thank you for your submission.

Sincerely,

Peter M Quesada

Peter M. Quesada, Ph.D., Chair

Social/Behavioral/Educational Institutional Review Board

PMQ/jsp

Full Accreditation since June 2005 by the Association for the Accreditation of Human Research Protection Programs, Inc.

APPENDIX II: Subject Informed Consent Document

UofL Institutional Review Boards
IRB NUMBER: 16.0130
IRB APPROVAL DATE: 04/01/2016
IRB EXPIRATION DATE: 03/31/2017

Subject Informed Consent Document

Mental Workload Measurement for Competitive Video Games

Investigator(s) name & address: Jason J. Saleem, Ph.D.
Department of Industrial Engineering,
J.B. Speed School of Engineering,
University of Louisville,
Louisville, KY, USA, 40292

Site(s) where study is to be conducted: University of Louisville speed school Vogt room 314.

Phone number for subjects to call for questions: (502) 852-2274

Introduction and Background Information

You are invited to participate in a research study. The study is being conducted by Dr. Jason J. Saleem, Mr. Dustin Weiler, and Mr. Jamal McFarland. The study is sponsored by the University of Louisville, Department of Industrial Engineering. The study will take place on the campus of University of Louisville Vogt building room 314. Approximately five subjects will be invited to participate.

Purpose

The purpose of this study is to increase awareness and understanding of mental workload measurement in regards to competitive gaming. In this experiment, three different measures of mental workload will be used to determine if the measures are sensitive to changes in gamers' mental workload during challenging gaming tasks. Physiological, secondary task, and subjective mental workload measures will be used. The data will be analyzed to determine levels of mental workload that gamers experience throughout a game as well as which mental workload measures are most appropriate for gaming tasks.

Procedures

In this study, you will be asked to play the computer game league of legends. While playing you will have to wear a Fitbit to continuously record your heart rate while you play. After each game you play you will then turn off the heart rate monitor and take a survey about your in game experience while playing. You will play 5 games under normal playing constraints and 5 games under high mental strain. In the high mental strain condition, I will ask you a series of math questions and you will have to answer then as fast as you can. And after each of those games you will again take a survey about your in game experience.

Potential Risks

There are no foreseeable risks associated with this study.

Mental Workload Measurement for Competitive Video Games

Benefits

A possible benefit f this study is learning that you go under a high mental stress when you play League of Legends. So you may learn that you should rest more often while between games. The information collected may not benefit you directly. The information learned in this study may be helpful to others.

Compensation

You will not be compensated for your time, inconvenience, or expenses while you are in this study.

Confidentiality

Total privacy cannot be guaranteed. Your privacy will be protected to the extent permitted by law. If the results from this study are published, your name will not be made public. While unlikely, the following may look at the study records:

The University of Louisville Institutional Review Board, Human Subjects Protection Program Office, and Privacy Office.

Security

Your information will be kept private by a password protected computer. No identifiers will be kept.

Voluntary Participation

Taking part in this study is voluntary. You may choose not to take part at all. If you decide to be in this study you may stop taking part at any time. If you decide not to be in this study or if you stop taking part at any time, you will not lose any benefits for which you may qualify.

You will be told about any changes that may affect your decision to continue in the study.

Research Subject's Rights, Questions, Concerns, and Complaints

If you have any concerns or complaints about the study or the study staff, you have three options.

You may contact the principal investigator at (502) 852-2274.

If you have any questions about your rights as a study subject, questions, concerns or complaints, you may call the Human Subjects Protection Program Office (HSPPO) (502) 852-5188. You may discuss any questions about your rights as a subject, in secret, with a member of the Institutional Review Board (IRB) or the HSPPO staff. The IRB is an

independent committee composed of members of the University community, staff of the institutions, as well as lay members of the community not connected with these institutions. The IRB has reviewed this study.

If you want to speak to a person outside the University, you may call 1-877-852-1167. You will be given the chance to talk about any questions, concerns or complaints in secret. This is a 24-hour hot line answered by people who do not work at the University of Louisville.

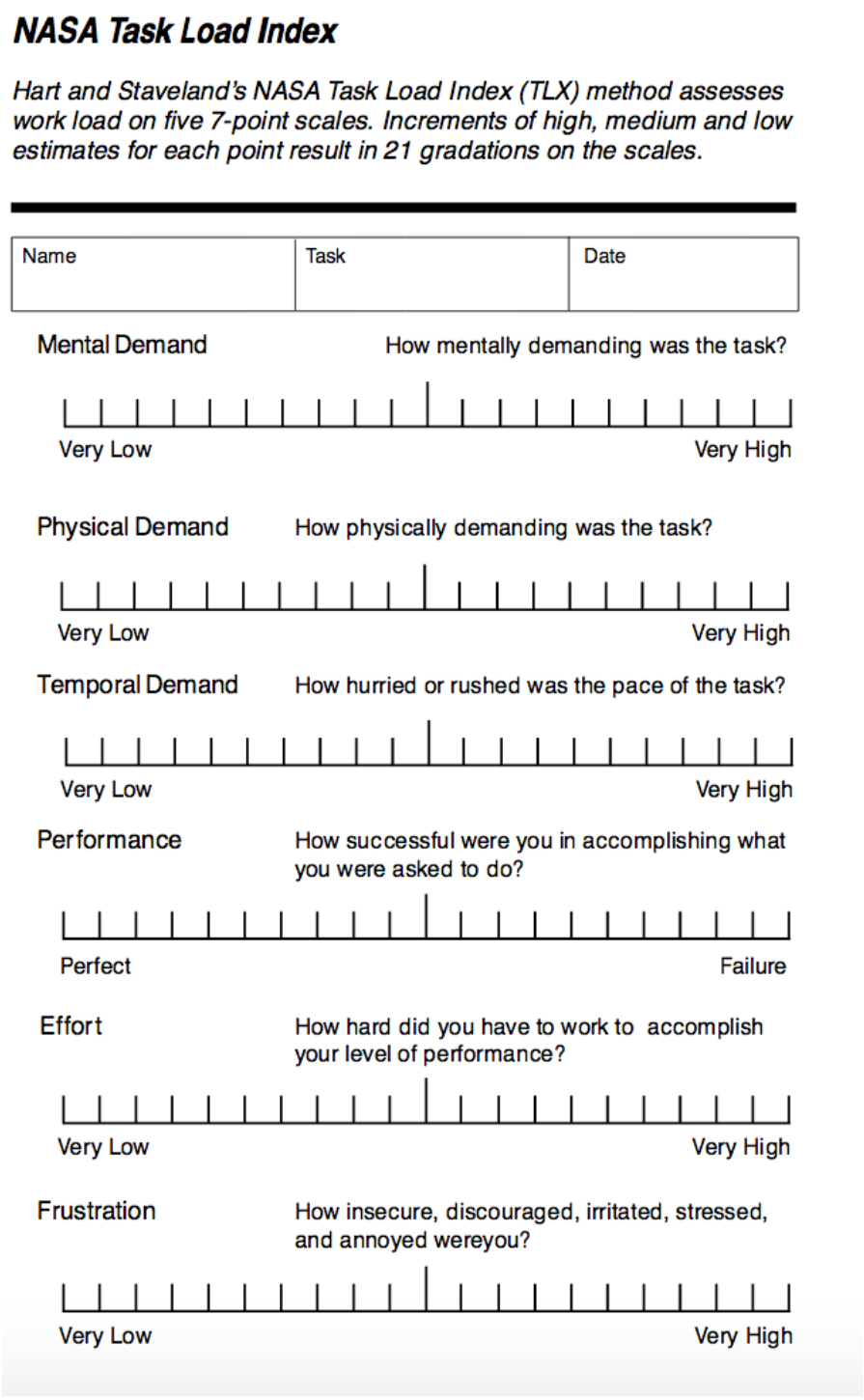
Acknowledgment and Signatures

This informed consent document is not a contract. This document tells you what will happen during the study if you choose to take part. Your signature indicates that this study has been explained to you, that your questions have been answered, and that you agree to take part in the study. You are not giving up any legal rights to which you are entitled by signing this informed consent document. You will be given a copy of this consent form to keep for your records.

Subject Name (Please Print)	Signature of Subject	Date Signed
Printed Name of Legal Representative (if applicable)	Signature of Legal Representative	Date Signed
Relationship of Legal Representative to Subject		
Printed Name of Person Explaining Consent Form	Signature of Person Explaining Consent Form (if other than the Investigator)	Date Signed
Printed Name of Investigator	Signature of Investigator	Date Signed

List of Investigators:	Phone Numbers:
Jason J. Saleem, Ph.D.	**(502) 852-2274**
Jamal McFarland	**(502) 759-7233**
Dustin Weiler	**(502) 852-2274**

APPENDIX III: NASA-TLX SURVEY



NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

Figure 8: NASA-TLX RATING SCALE DEFINITIONS

Title	Endpoints	Descriptions
MENTAL DEMAND	Low /High	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	Low /High	How much physical activity was required (e.g.. pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous. restful or laborious?
TEMPORAL DEMAND	Low/ High	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
PERFORMANCE	good/poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
EFFORT	Low/High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
FRUSTRATION LEVELi	Low /High	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

APPENDIX IV: Mental Arithmetic Score Sheet

Math

Game 1					
		1	2	3	4
Num	Ans				
79	86				
4	11				
57	64				
39	46				
93	100				
47	54	x			
50	57				
29	36				
1	8				
75	82		x		
53	60				
76	83			x	
41	48				
33	40				
34	41	x			
84	91				
12	19				
55	62	x			
82	89				
26	33	x			
91	98				
8	15	x			x
73	80				
15	22				
28	35	x			x
53	60	x			
15	22				
56	63		x	x	
68	75				
84	91				
31	38				
67	74				

82	89		x		
57	64				
57	64				
54	61			x	
50	57			x	
23	30			x	
25	32				
18	25				
55	62				
6	13			x	x
78	85	x			
33	40				
27	34			x	
23	30				
75	82				
16	23				
73	80				
7	14				
16	23	x		x	x
71	78				
72	79				x
66	73	x		x	
29	36	x			
90	97				
28	35				
8	15	x			
13	20				
54	61	x			
71	78	x			
71	78				
67	74				
45	52	x			
77	84				
35	42				
56	63				x
34	41		x		
93	100				
23	30				
78	85				x

29	36	x			x
3	10				
49	56	x			
19	26				
71	78			x	x
54	61	x	x	x	x
38	45				
2	9				x
27	34		x		
73	80				
82	89				
68	75				
89	96				
63	70		2		
1	8				
20	27				
17	24				
32	39				
54	61	x			
75	82	x			x
90	97				
14	21				
42	49	x			
10	17		x		x
17	24				
41	48				
90	97				
58	65				
84	91				
83	90				
71	78	x			x
25	32				
87	94		x		
79	86				
66	73				
18	25				
84	91				
46	53				
50	57				

20	27			x	
82	89				
79	86				
19	26				
7	14				
11	18				
86	93				
15	22	x			
72	79	x			
54	61				
76	83				
57	64				
61	68				
3	10				
79	86				
52	59				
34	41				
39	46				
6	13				
31	38				
78	85				
31	38		x		
28	35				
6	13				x
6	13				
53	60				
64	71				
11	18				
41	48				
62	69				
22	29				
40	47				
47	54	x			
23	30				
67	74		x		x
75	82	End			
66	73				
33	40				
15	22				

59	66	25	10	12	16
37	44	0.827586207	0.931034483	0.917241379	0.889655172

Game 2					
		1	2	3	4
Num	Ans				
54	61				
39	46				
6	13			x	
9	16	x			
25	32				
34	41				
60	67		x		
80	87				
39	46				
38	45				
2	9				
67	74				
90	97				
49	56				
57	64				
88	95				x
58	65			x	x
59	66				
74	81				
53	60				
6	13				x
54	61				
28	35	x	x		x
63	70				x
77	84	x			
57	64	x			
55	62				
12	19				
40	47				
52	59				
13	20				x
4	11				

8	15				
87	94	x	x		x
69	76				x
71	78				
30	37				
85	92				
63	70				
55	62				
42	49				x
54	61	x			
16	23				x
50	57				
39	46				
21	28				
48	55				x
75	82				x
93	100				
79	86				
46	53	x	x		x
63	70				x
11	18	x		x	x
22	29				
54	61				
35	42	x			x
38	45				
80	87				
91	98				
74	81				
25	32				
18	25	x			
47	54				
75	82	x			
49	56	x			x
33	40				
61	68				x
8	15	x			
27	34				
34	41				
41	48	x			

17	24				
69	76	x			
31	38				
67	74				x
24	31				
14	21				
20	27				
73	80		x		
82	89				
23	30				
28	35				
91	98				
87	94				
91	98				
8	15				
43	50				
51	58				
49	56	end			
31	38				
48	55	15	5	3	19
42	49	0.831460674	0.943820225	0.966292135	0.786516854

Game 4					
		1	2	3	4
Num	Ans				
18	25				
7	14				
11	18				
24	31				x
5	12			x	
10	17				
74	81	x		x	
31	38				
42	49				
84	91				

79	86				
47	54				
45	52	x	x		
36	43				
29	36				
37	44		x		
92	99	x			
32	39				
10	17				
65	72	x			
23	30				
35	42		x		x
62	69				
6	13	x			x
16	23	x			x
47	54				
58	65				
3	10	x	x		
64	71	x		x	
1	8				
79	86			x	
3	10				
59	66				x
80	87				
60	67				
93	100		x		
12	19			x	
78	85	x			x
69	76				
36	43	x		x	x
16	23				x
70	77				
74	81				
81	88				
86	93	x			x
83	90				
85	92		x		
14	21			x	
38	45				

14	21				
58	65	x			x
69	76				
86	93				
34	41				x
38	45	x			x
8	15				
58	65				
88	95		x		x
87	94				
50	57				
57	64				
24	31				
86	93				
30	37				
6	13	x			
43	50				
25	32				x
66	73	x	x		x
78	85				
91	98				
27	34	x			
46	53				
81	88				
72	79				
3	10				x
6	13			x	
67	74		x		
65	72				x
20	27				
28	35				
88	95	x			x
80	87				
4	11				
16	23				
15	22	x	x	x	x
16	23				
58	65				x
90	97				

31	38		x		
48	55				
6	13	x	x	x	x
51	58				
72	79	End			
8	15				
73	80	19	12	10	21
92	99	0.793478261	0.869565217	0.891304348	0.77173913

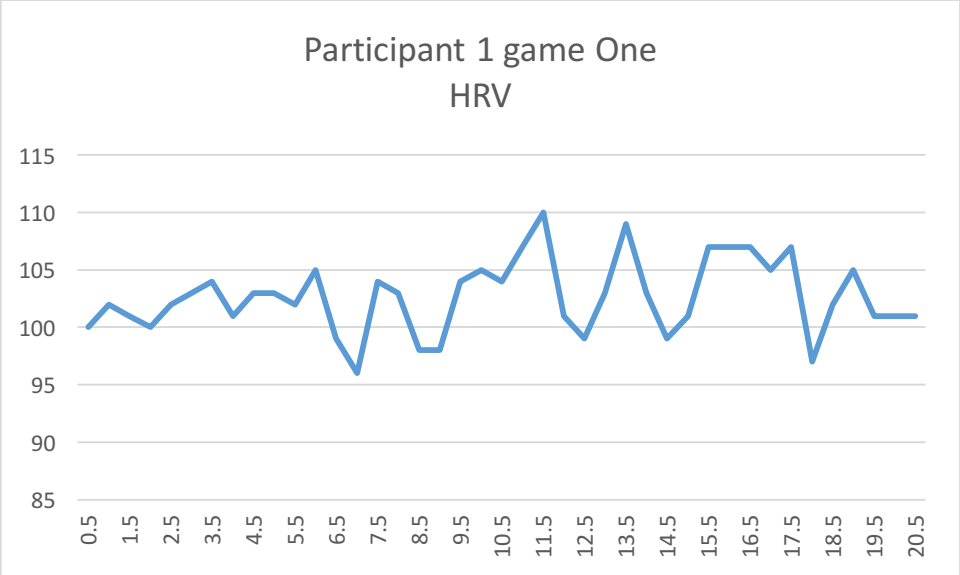
Game 5					
		1	2	3	4
Num	Ans				
49	56				
50	57				
1	8				
59	66			x	x
91	98			x	x
55	62				
5	12				
65	72	x	x		
70	77				
7	14				
91	98				
67	74				
57	64				
36	43	x	x		
53	60				
22	29				
44	51	x			
78	85				
14	21				
19	26				
7	14	x		x	
90	97				
74	81	x			
88	95				x
52	59				
83	90				x

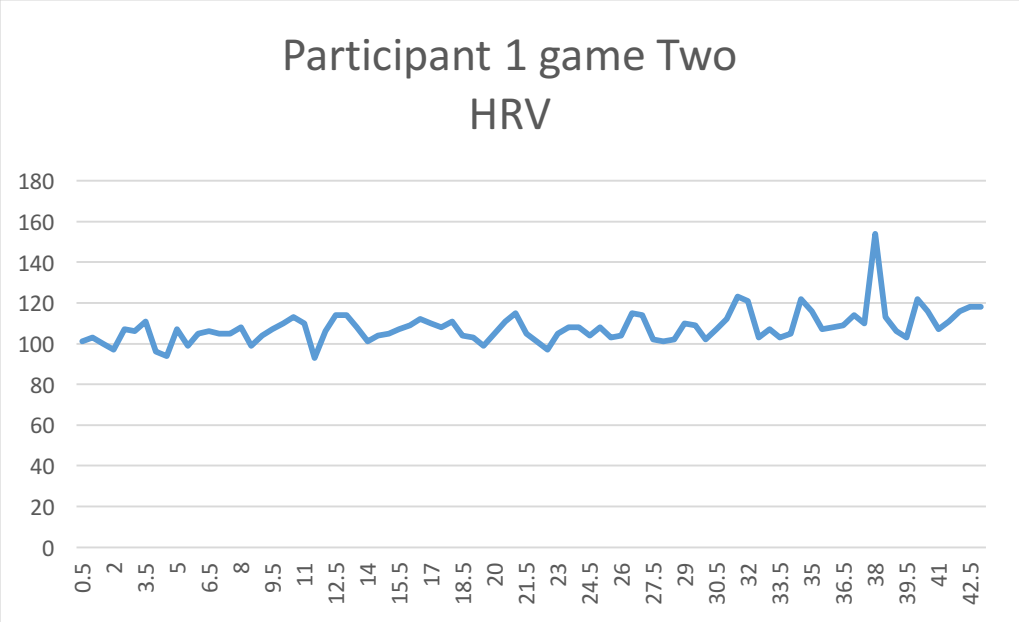
51	58				
32	39		x		x
72	79				
52	59				
25	32	x			x
11	18				
37	44				
60	67				x
24	31	x			x
53	60				x
90	97				
69	76	x			
85	92				x
63	70				
10	17				
44	51	x		x	
46	53				
80	87				
79	86				
52	59				
23	30				x
27	34				
49	56				x
66	73	x			
46	53	x			
88	95				
5	12				
68	75				x
71	78				
59	66	x			
8	15	x			
6	13				x
3	10				
61	68				
11	18		x		
48	55	x			
56	63	x			
4	11				
21	28				

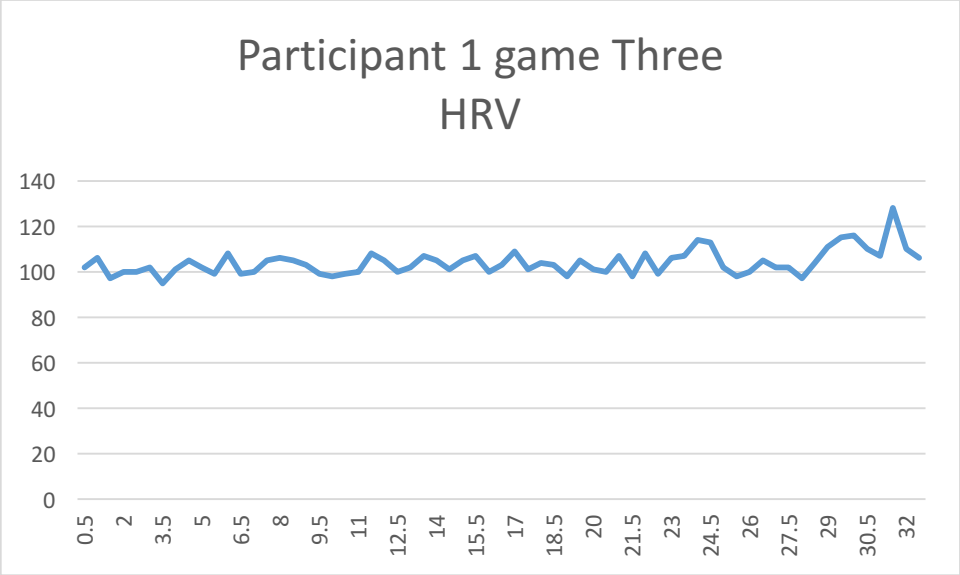
16	23	x			x
58	65	x			x
18	25				x
78	85	x			
62	69				
41	48				x
34	41				
53	60				
69	76				x
80	87				
66	73				x
87	94		x		
49	56	x			x
24	31				
90	97				
37	44				
72	79				
87	94				
59	66	x			x
92	99		x		x
29	36				
9	16				x
53	60				
11	18				
37	44	x		x	x
1	8				
76	83	x			x
64	71	x			x
2	9	x			
7	14				
64	71				
51	58		x		
89	96			x	
16	23	x			
74	81	x			x
13	20		x		x
50	57				
93	100				
87	94				

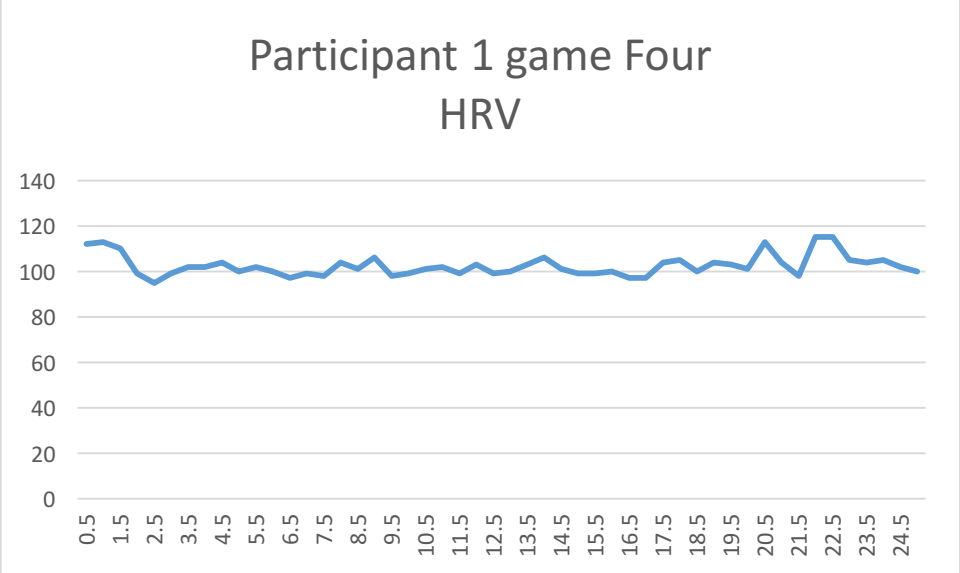
59	66				
2	9				
38	45				
83	90				
17	24				
32	39				
27	34				
19	26				x
47	54	x			x
3	10	END			
31	38				
62	69				
40	47	27	8	6	31
90	97	0.761061947	0.92920354	0.946902655	0.725663717

APPENDIX V: Heart Rate Graphs






Participant 1 game Three
HRV
140
120
100
80
60
40
20
0
0.5
2
3.5
5
6.5
8
9.5
11
12.5
14
15.5
17
18.5
20
21.5
23
24.5
26
27.5
29
30.5
32


Participant 1 game Four
HRV
140
120
100
80
60
40
20
0
0.5
1.5
2.5
3.5
4.5
5.5
6.5
7.5
8.5
9.5
10.5
11.5
12.5
13.5
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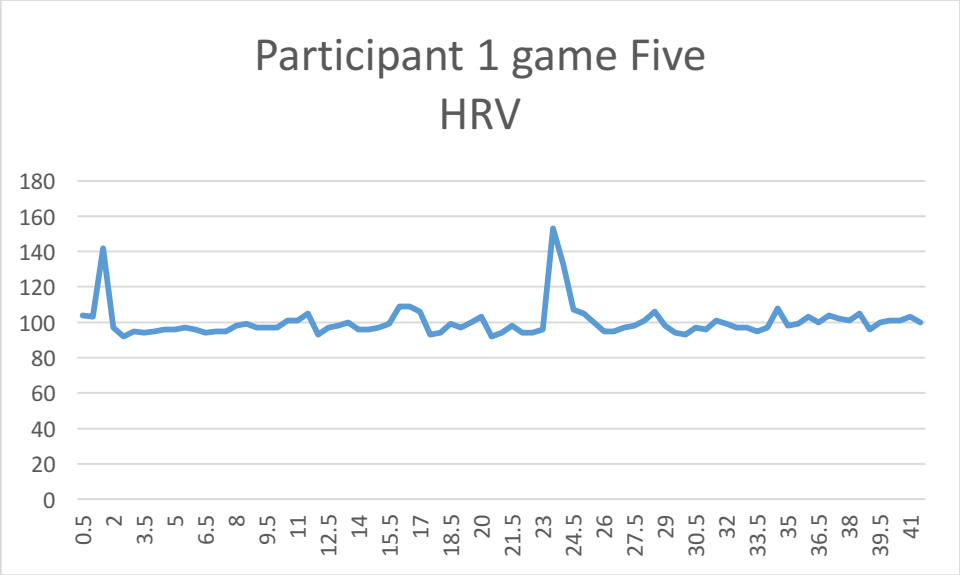
19.5
20.5
21.5
22.5
23.5
24.5


Participant 1 game Five
HRV
180
160
140
120
100
80
60
40
20
0
0.5
2
3.5
5
6.5
8
9.5
11
12.5
14
15.5
17
18.5
20
21.5
23
24.5
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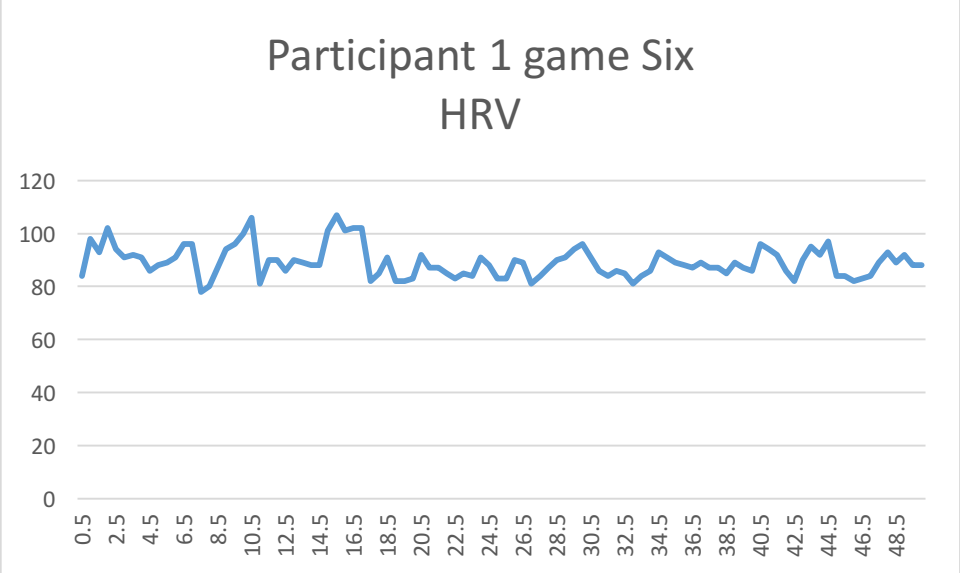
27.5
29
30.5
32
33.5
35
36.5
38
39.5
41


Participant 1 game Six
HRV
120
100
80
60
40
20
0
0.5
2.5
4.5
6.5
8.5
10.5
12.5
14.5
16.5
18.5
20.5
22.5
24.5
26.5
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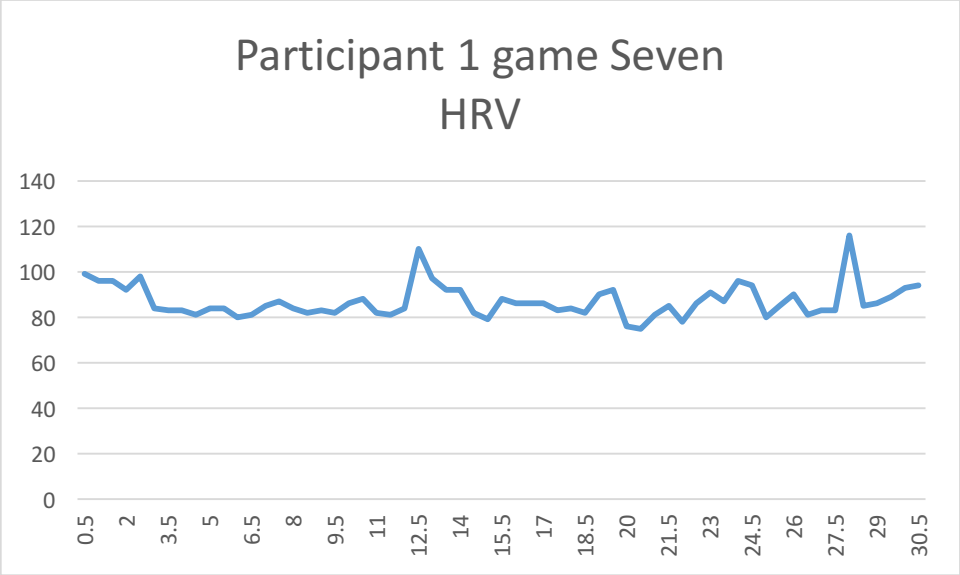
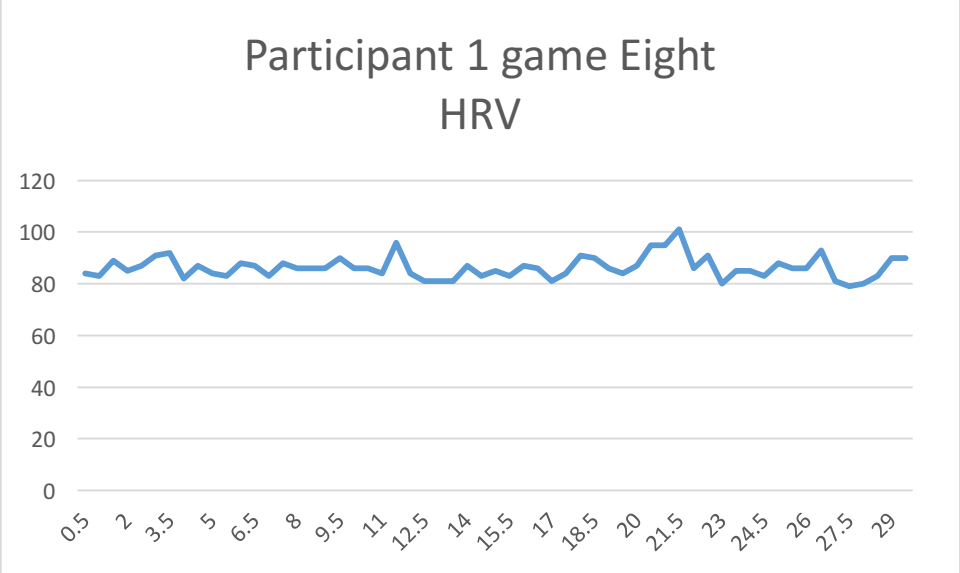
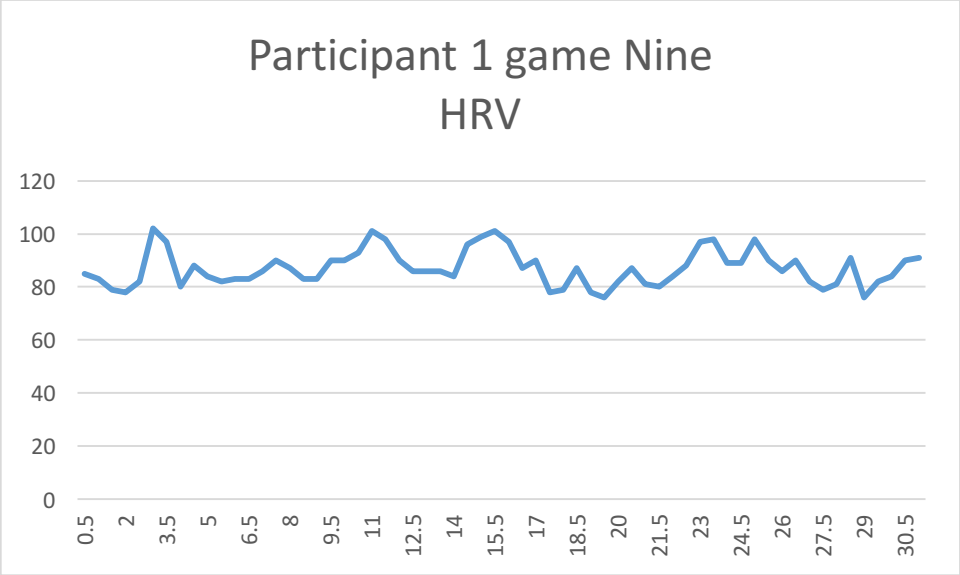
38.5
40.5
42.5
44.5
46.5
48.5


Participant 1 game Seven
HRV
140
120
100
80
60
40
20
0
0.5
2
3.5
5
6.5
8
9.5
11
12.5
14
15.5
17
18.5
20
21.5
23
24.5
26
27.5
29
30.5


Participant 1 game Eight
HRV
120
100
80
60
40
20
0
0.5
2
3.5
5
6.5
8
9.5
11
12.5
14
15.5
17
18.5
20
21.5
23
24.5
26
27.5
29


Participant 1 game Nine
HRV
120
100
80
60
40
20
0
0.5
2
3.5
5
6.5
8
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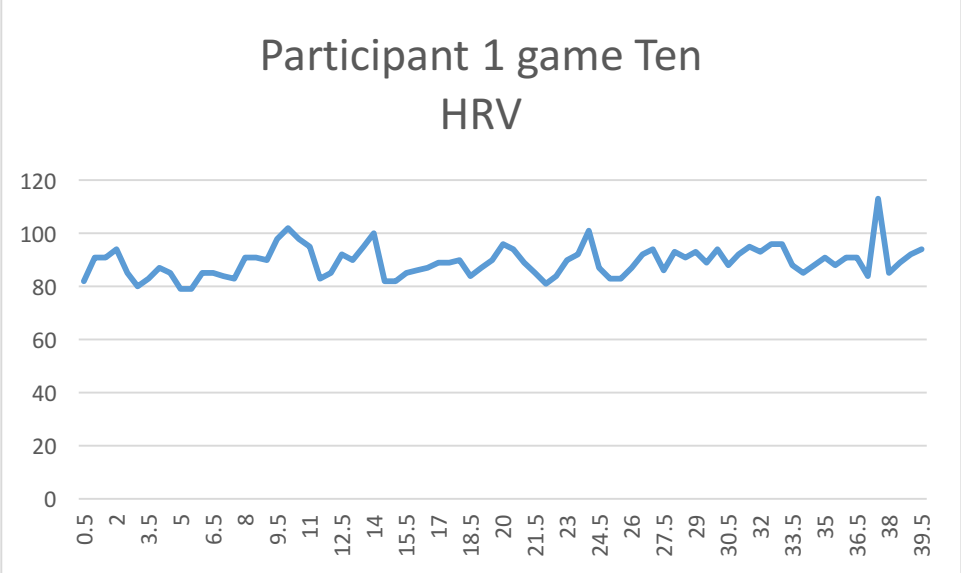
21.5
23
24.5
26
27.5
29
30.5


Participant 1 game Ten
HRV
120
100
80
60
40
20
0
0.5
2
3.5
5
6.5
8
9.5
11
12.5
14
15.5
17
18.5
20
21.5
23
24.5
26
27.5
29
30.5
32
33.5
35
36.5
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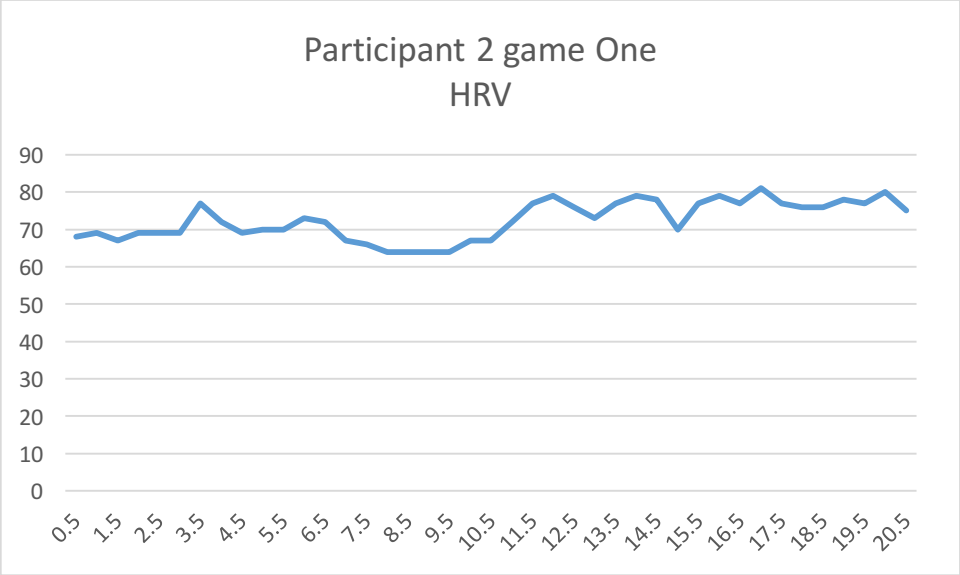
39.5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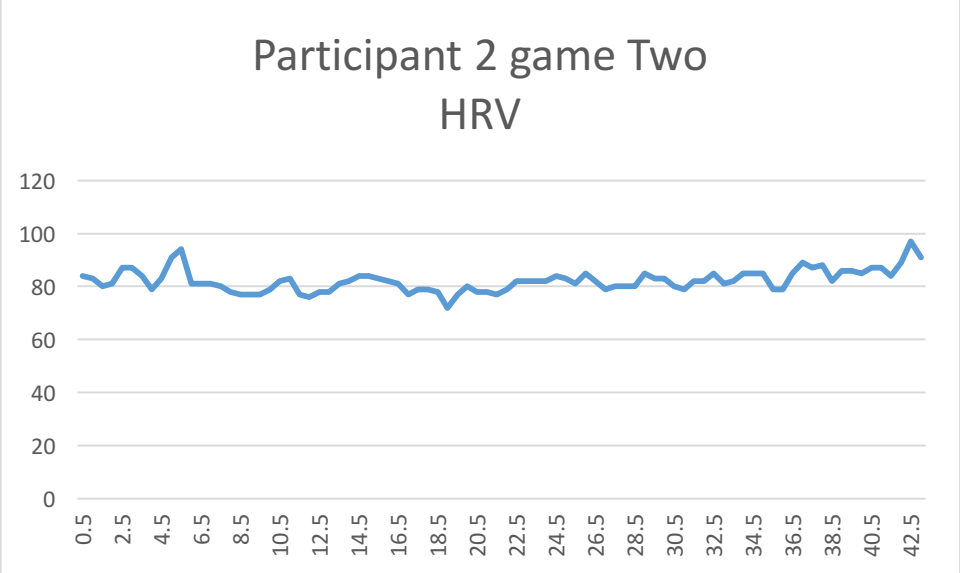
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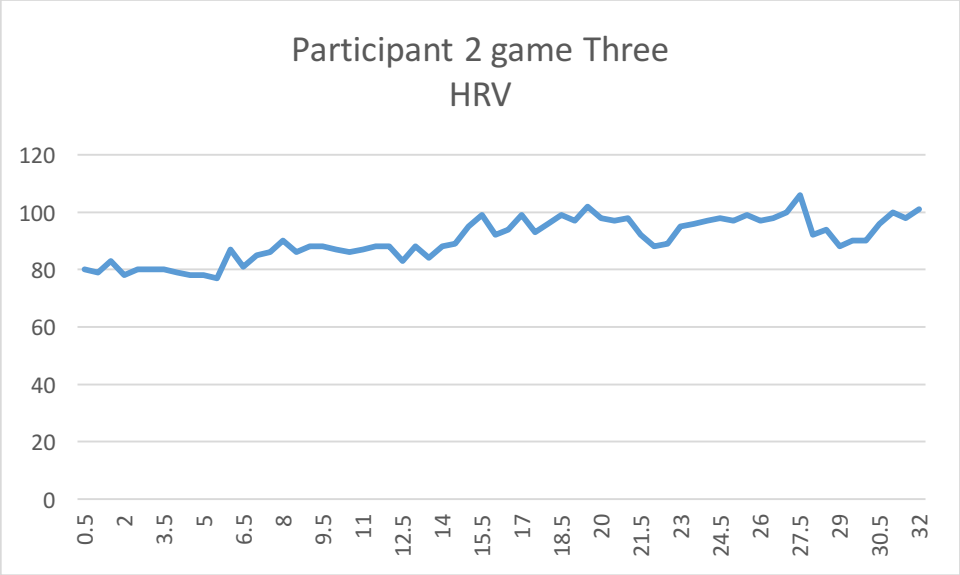
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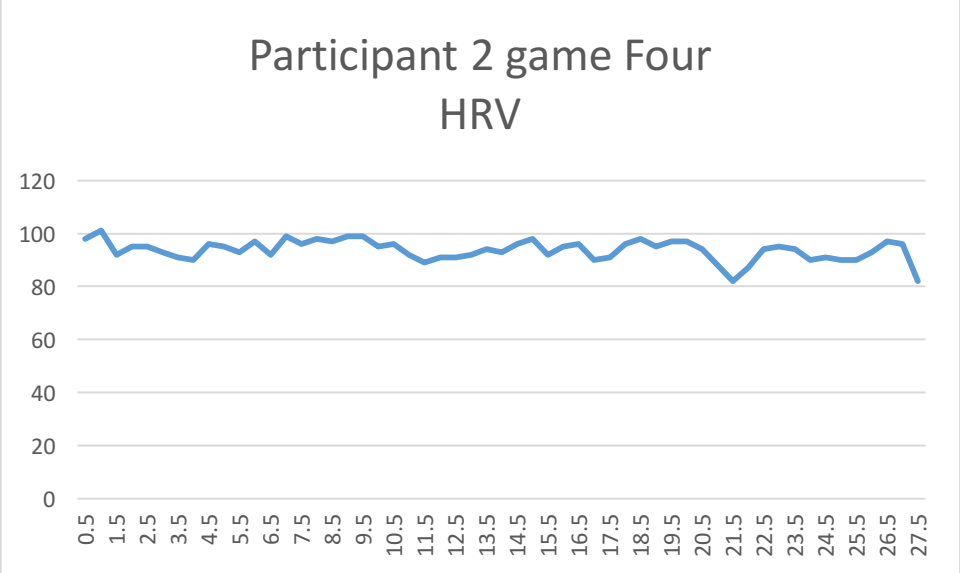
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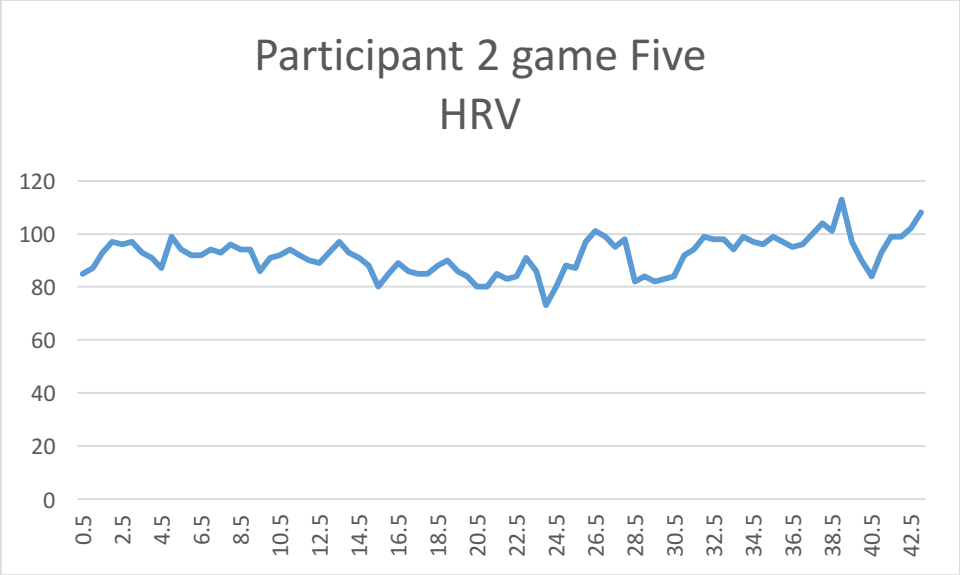
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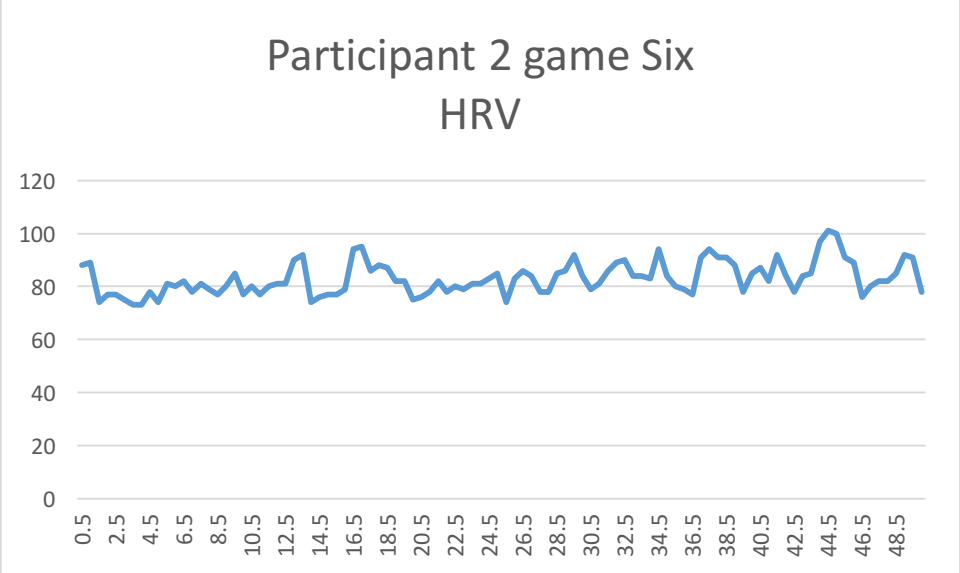
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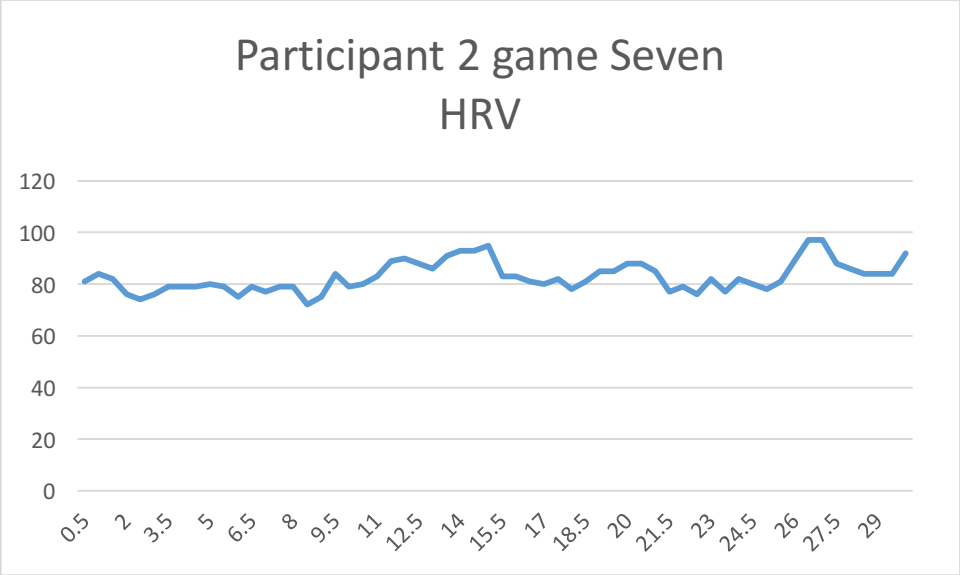
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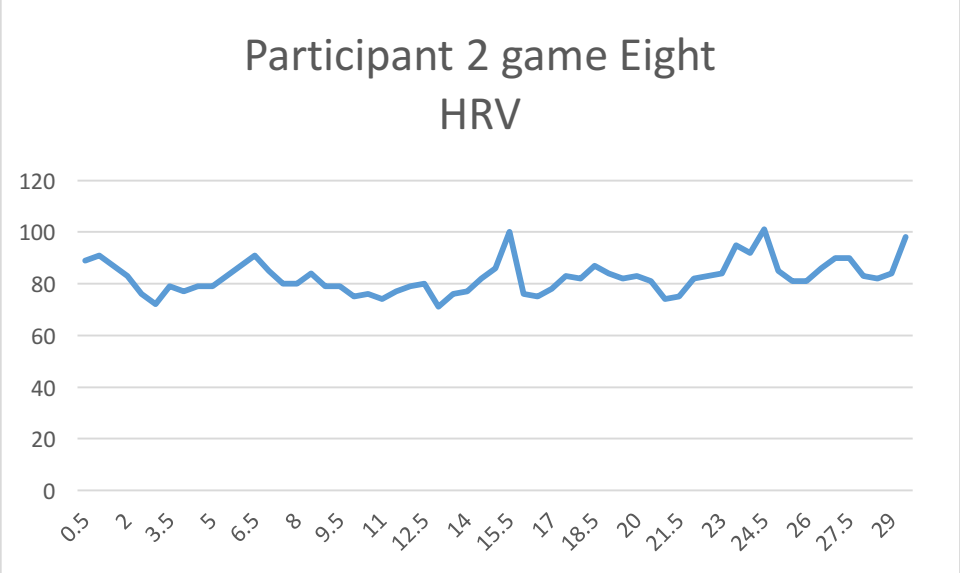
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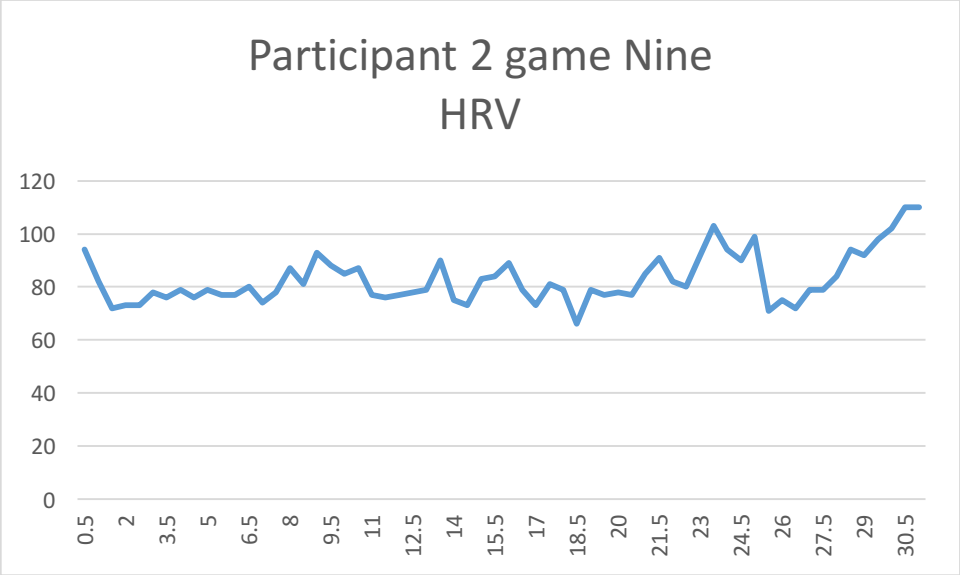
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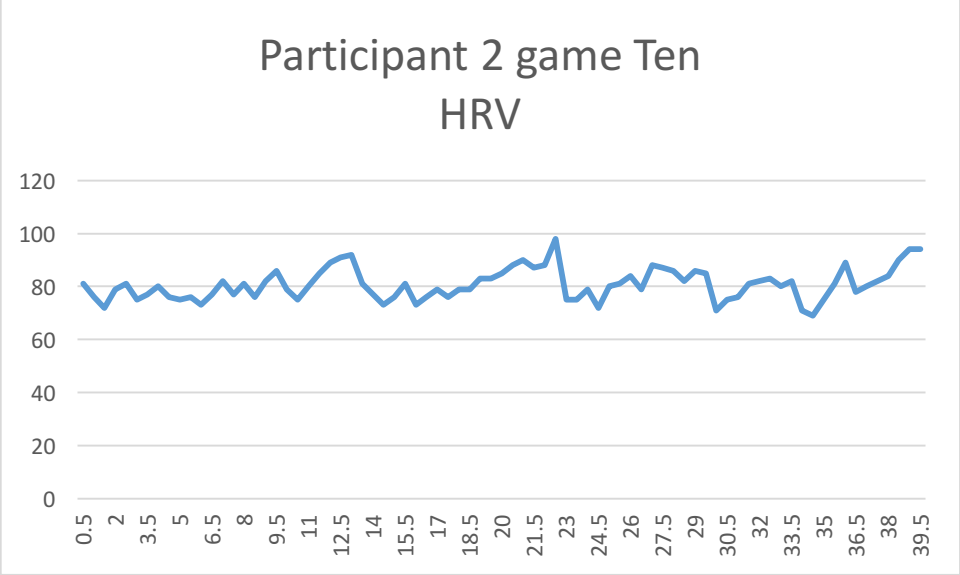
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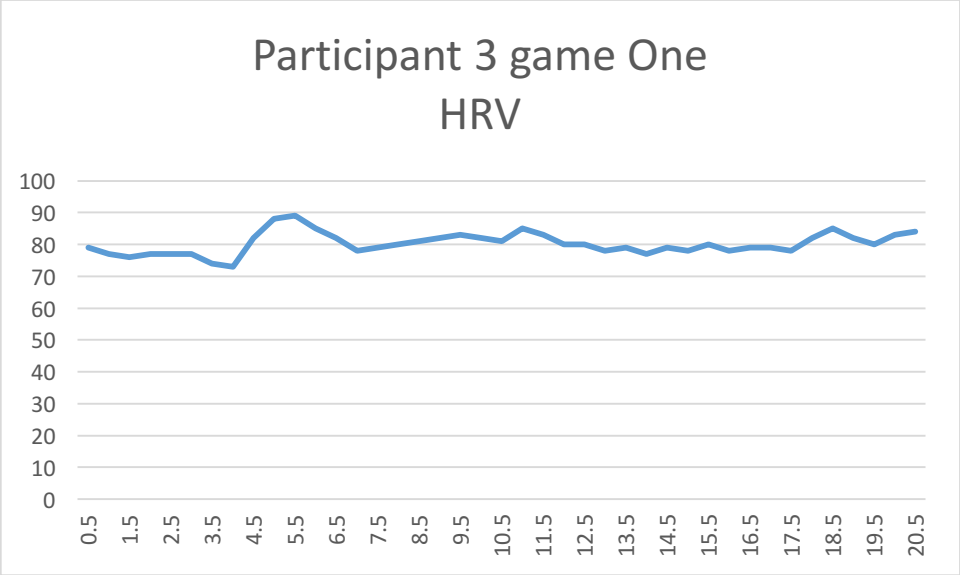
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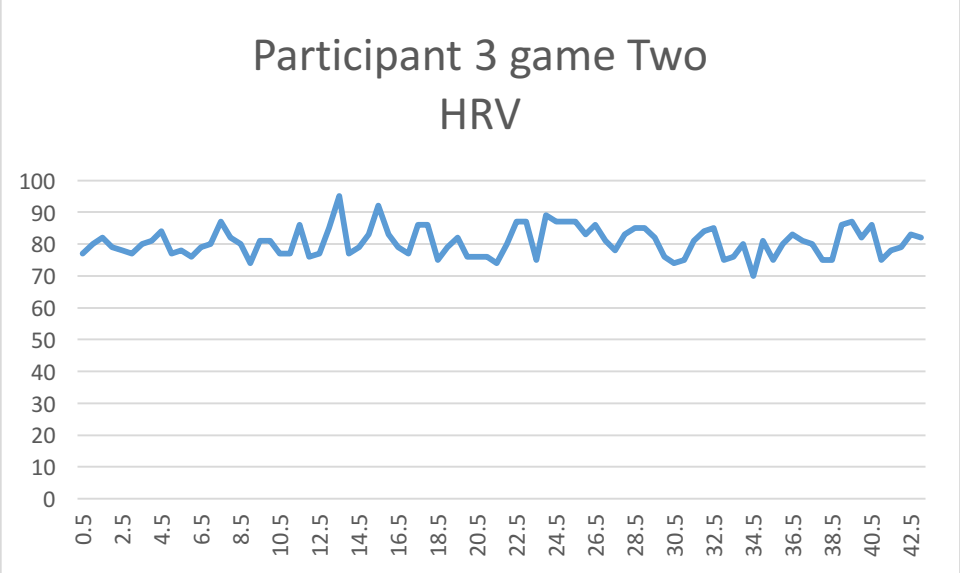
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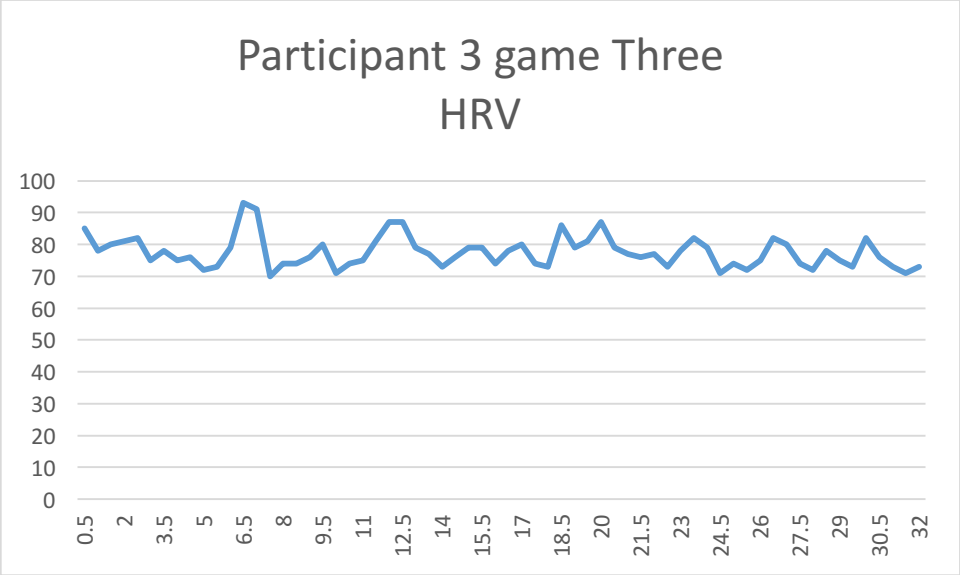
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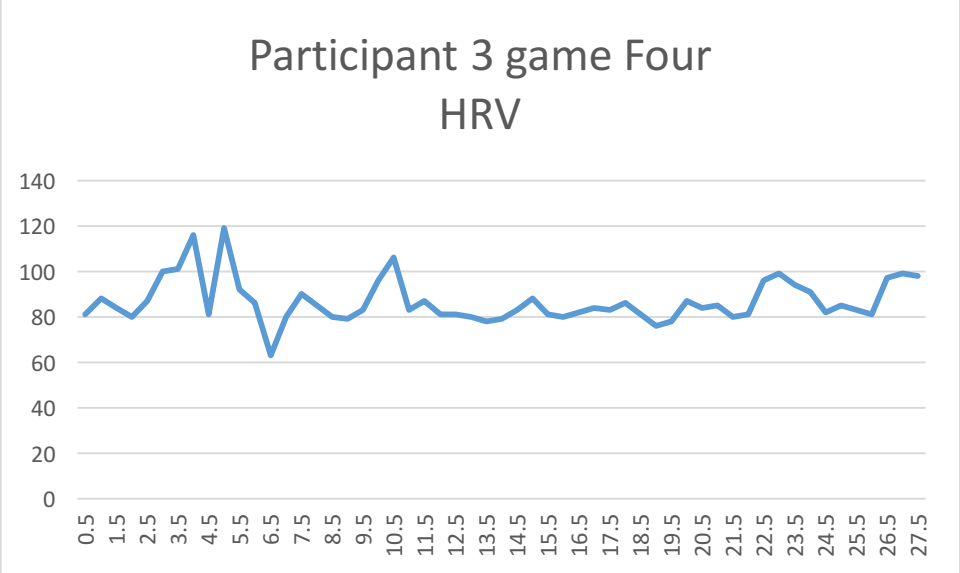
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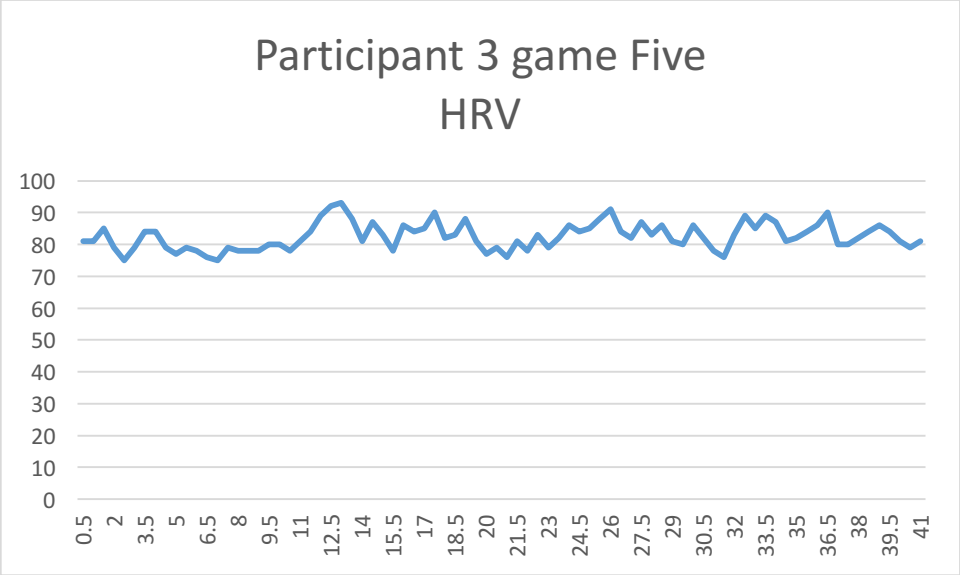
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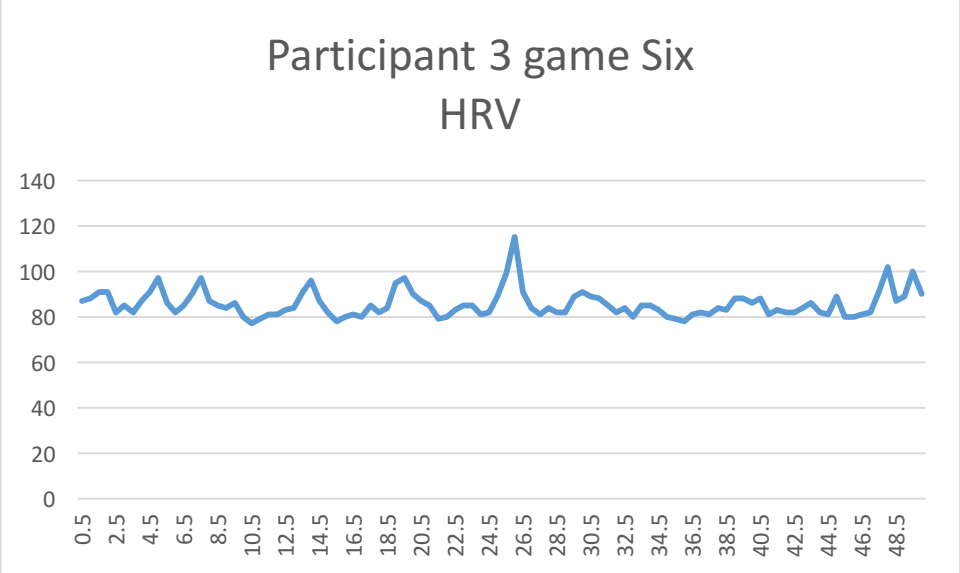
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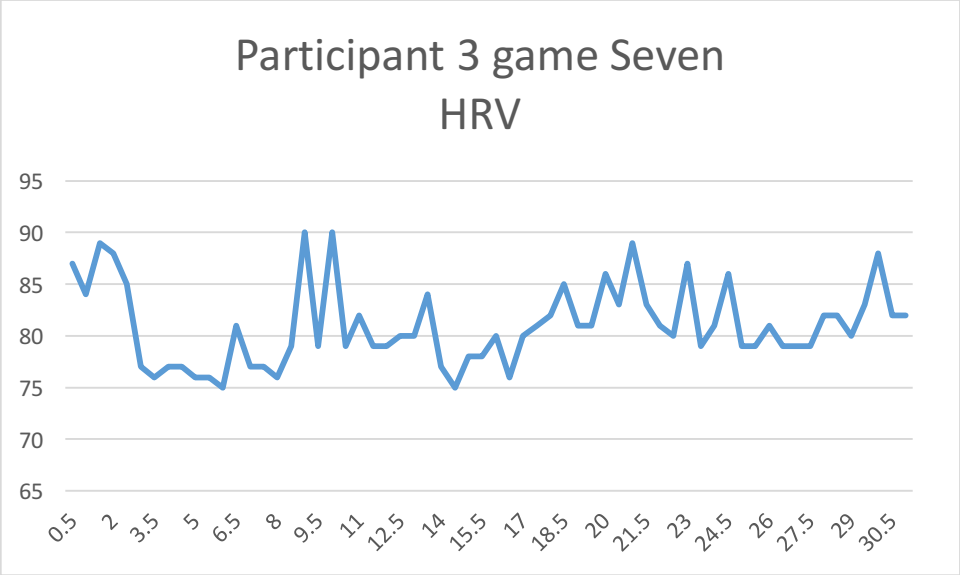
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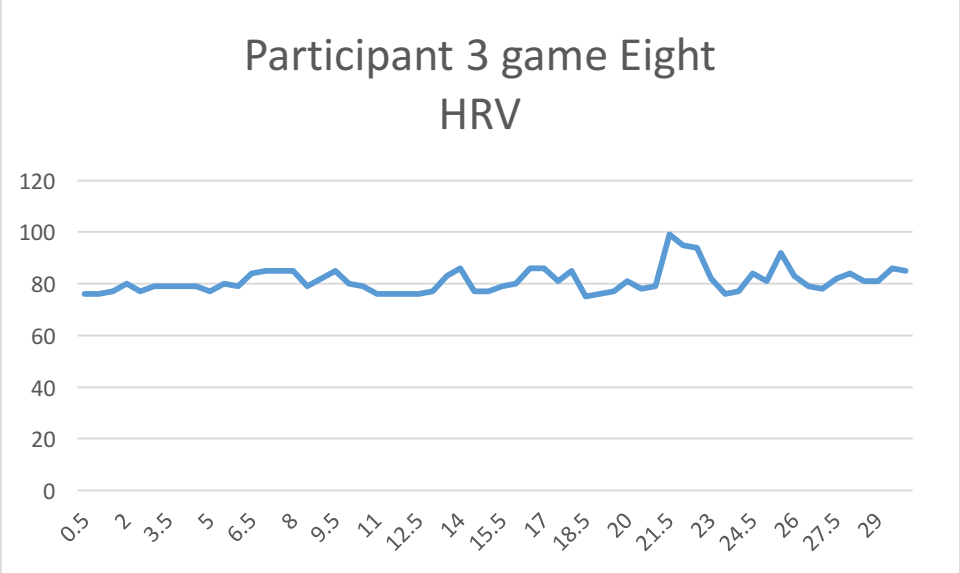
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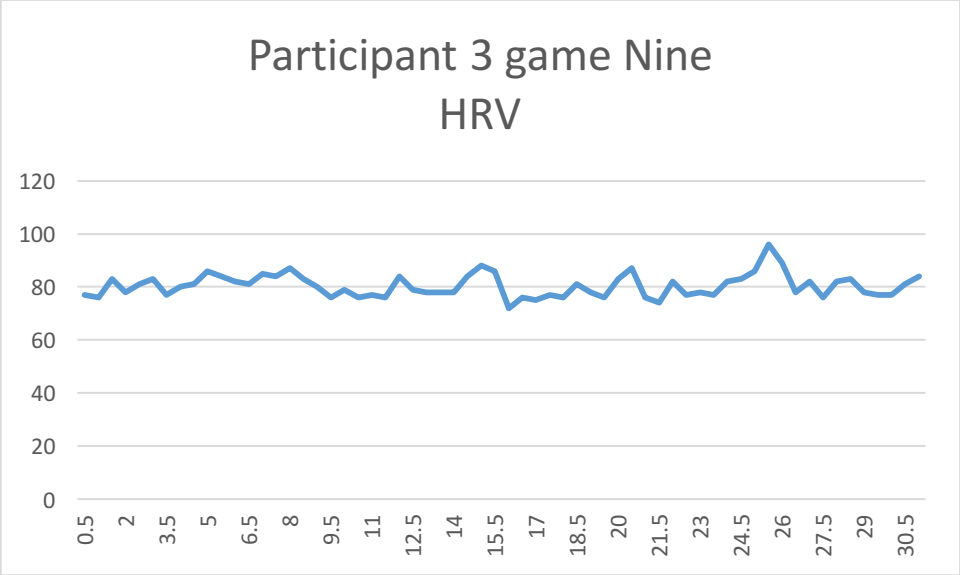
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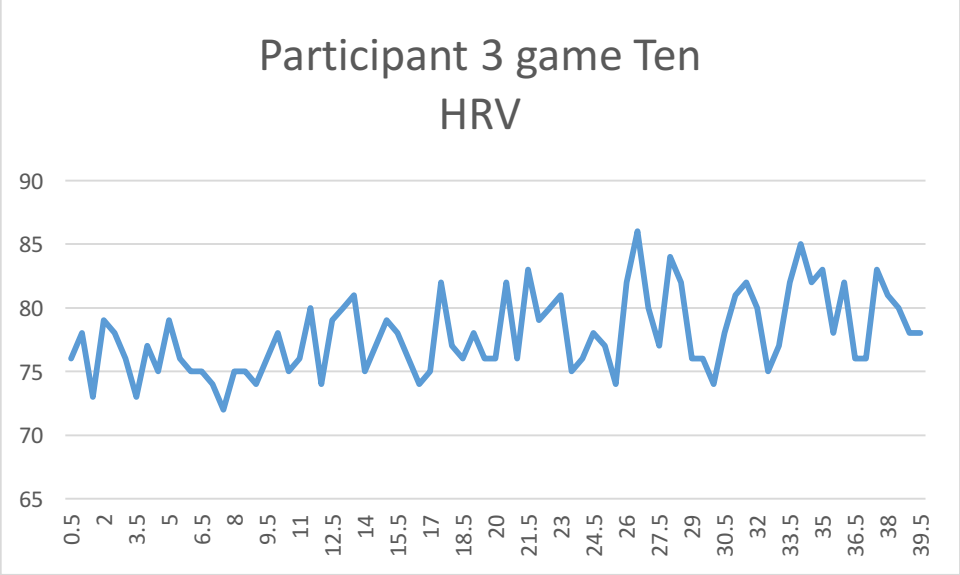
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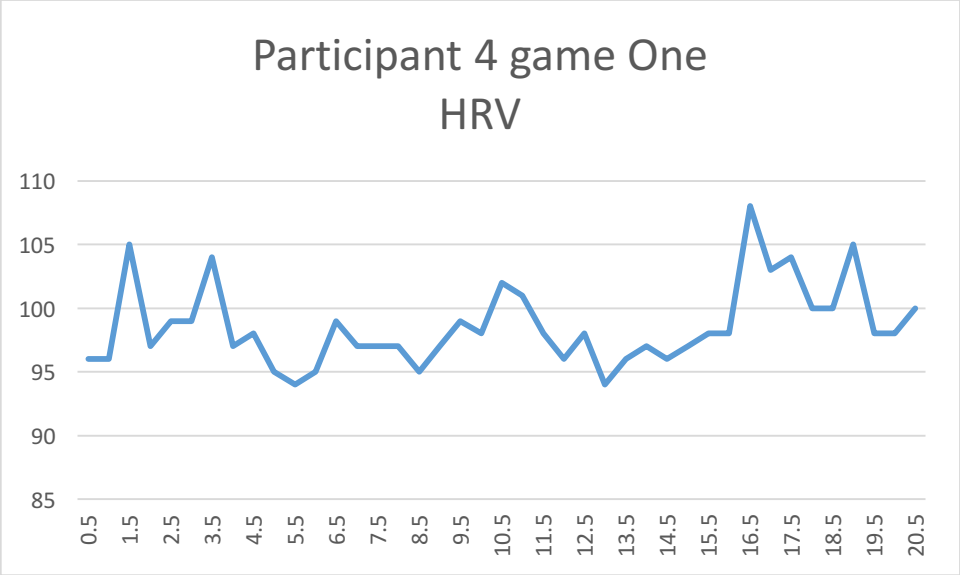
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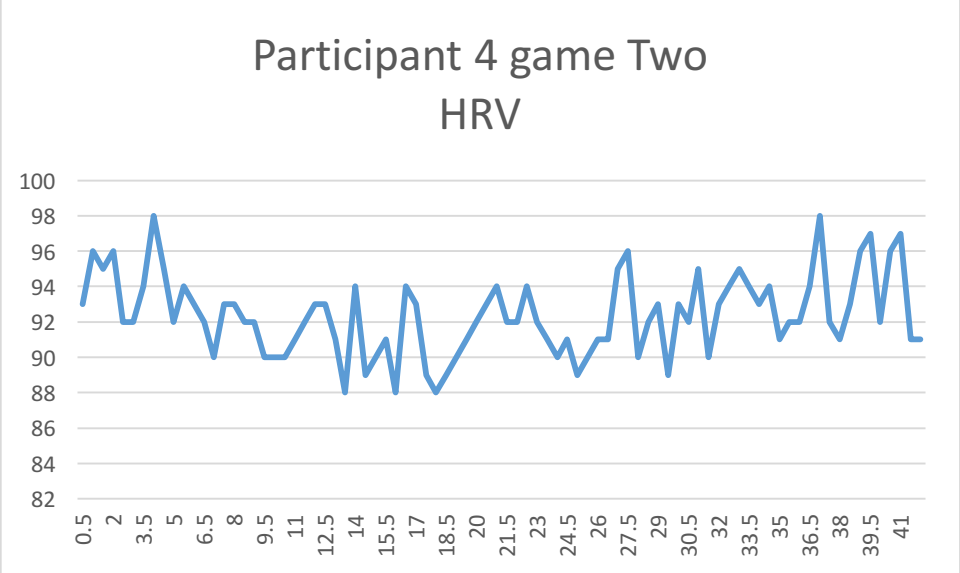
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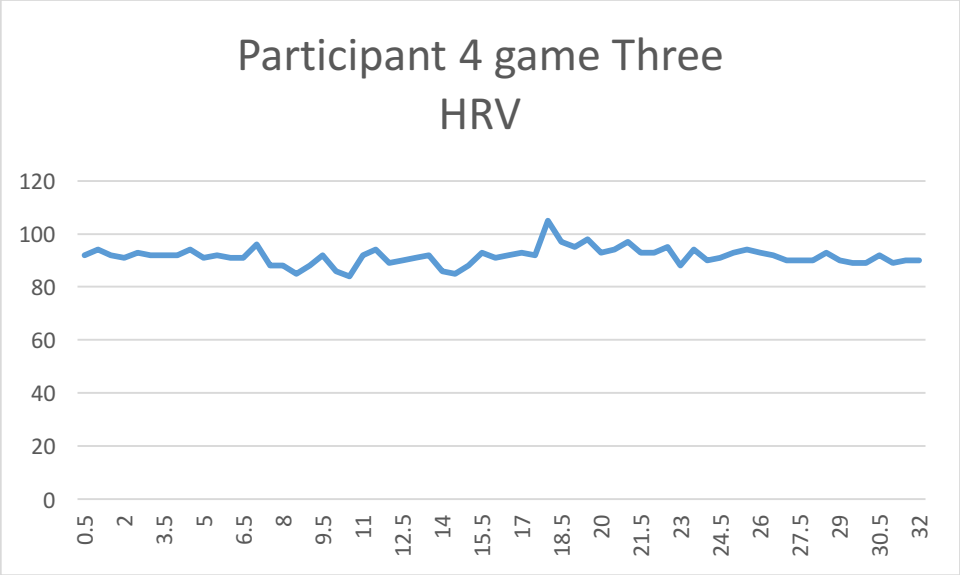
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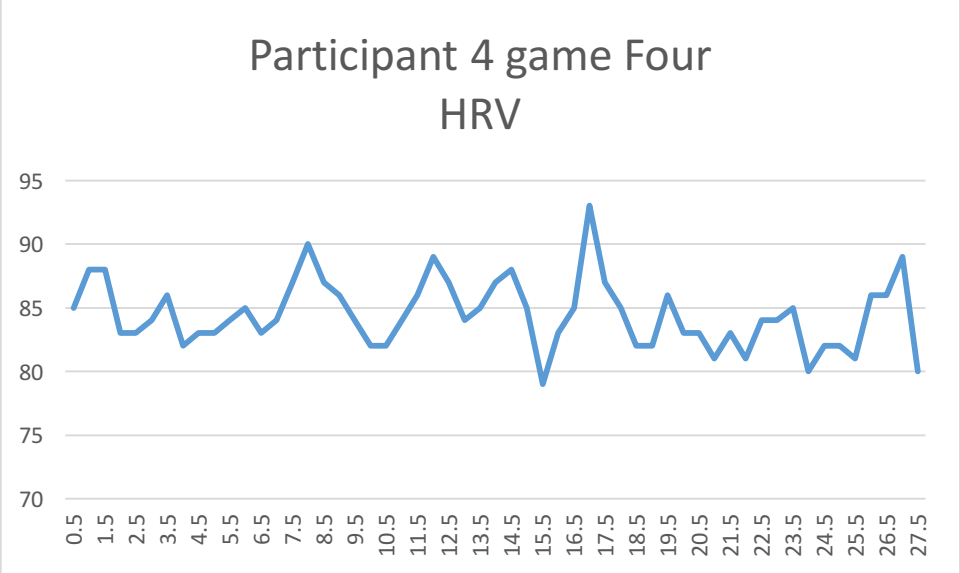
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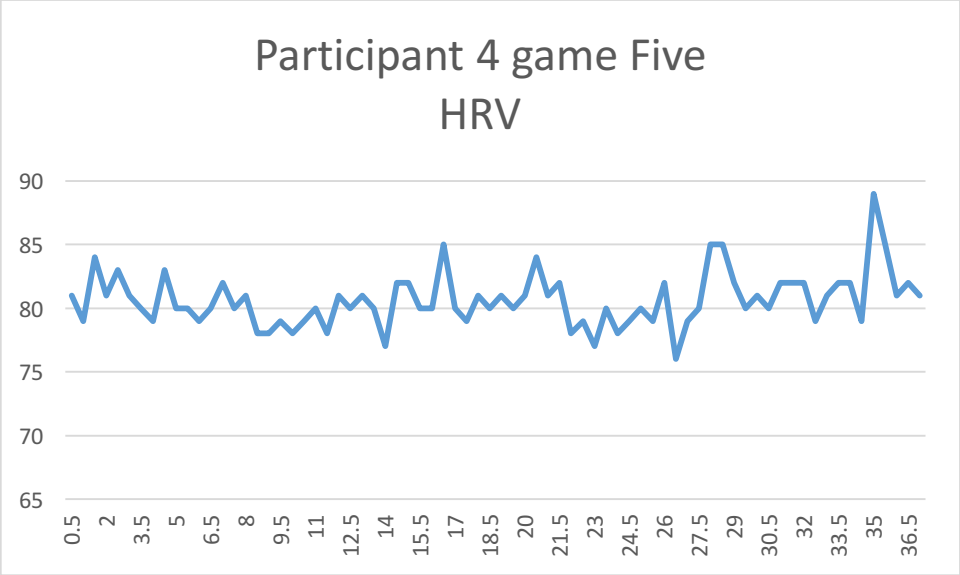
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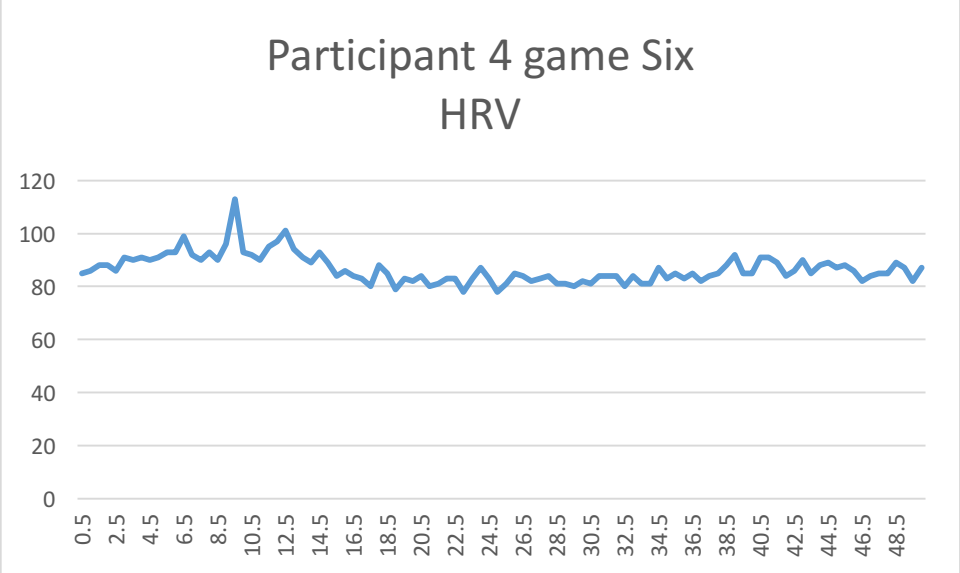
Participant 4 game Six
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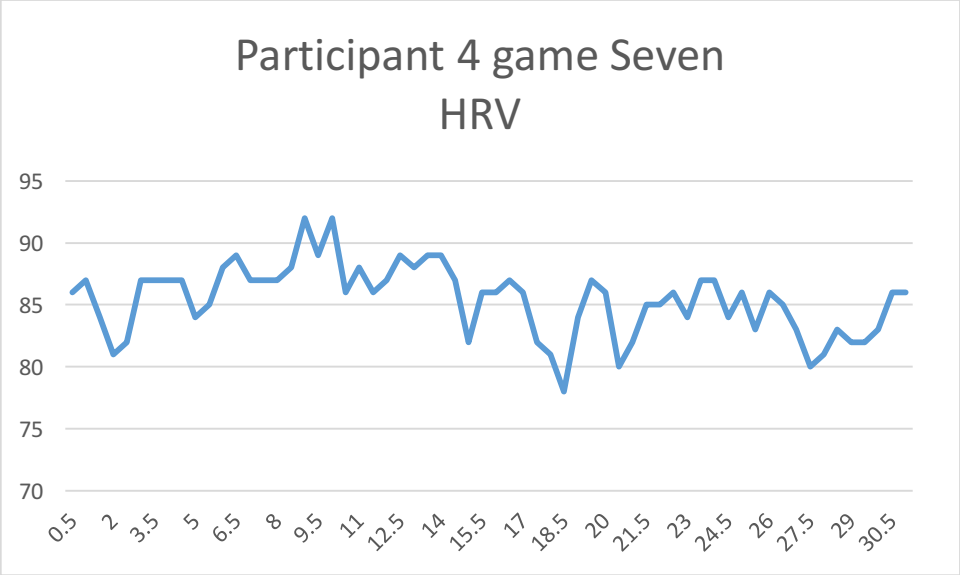
Participant 4 game Seven
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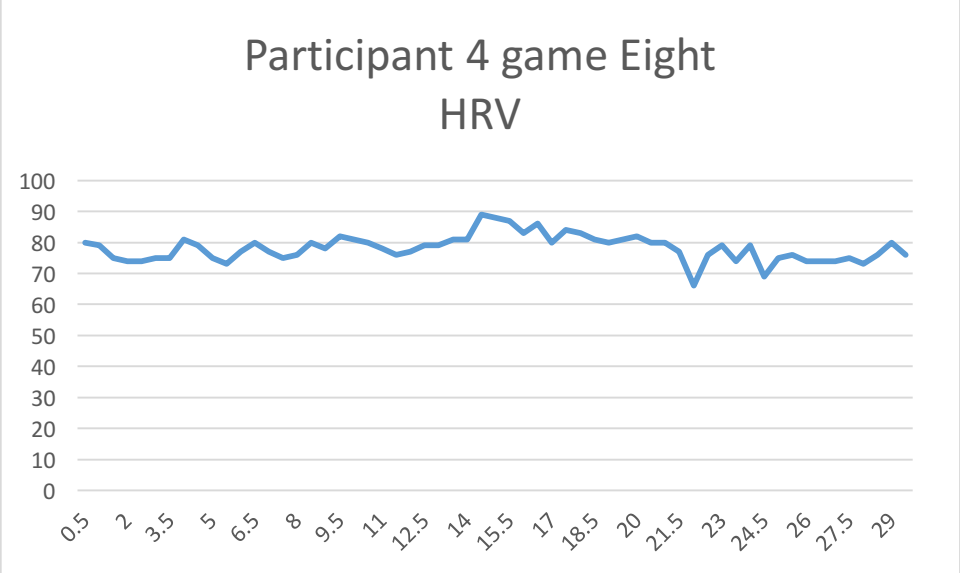
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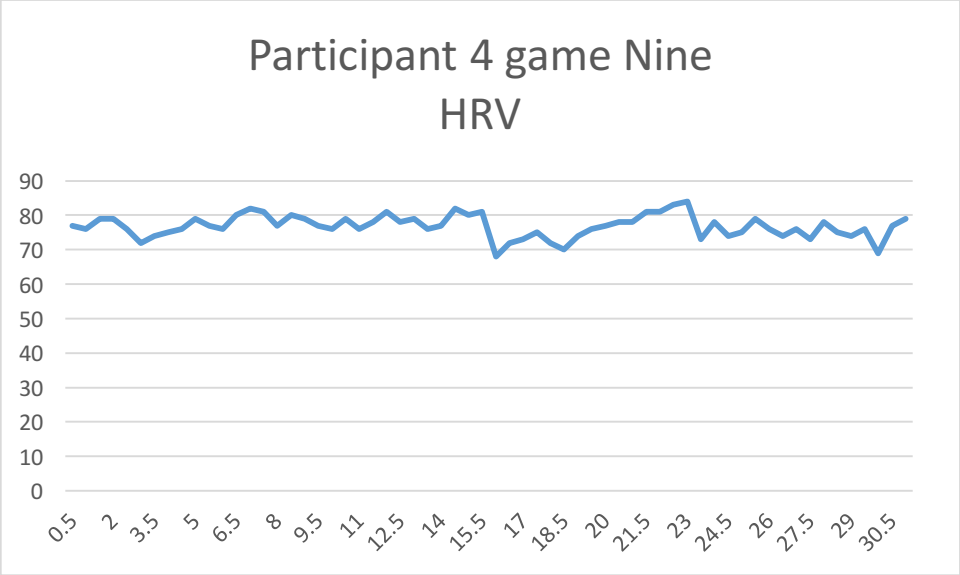
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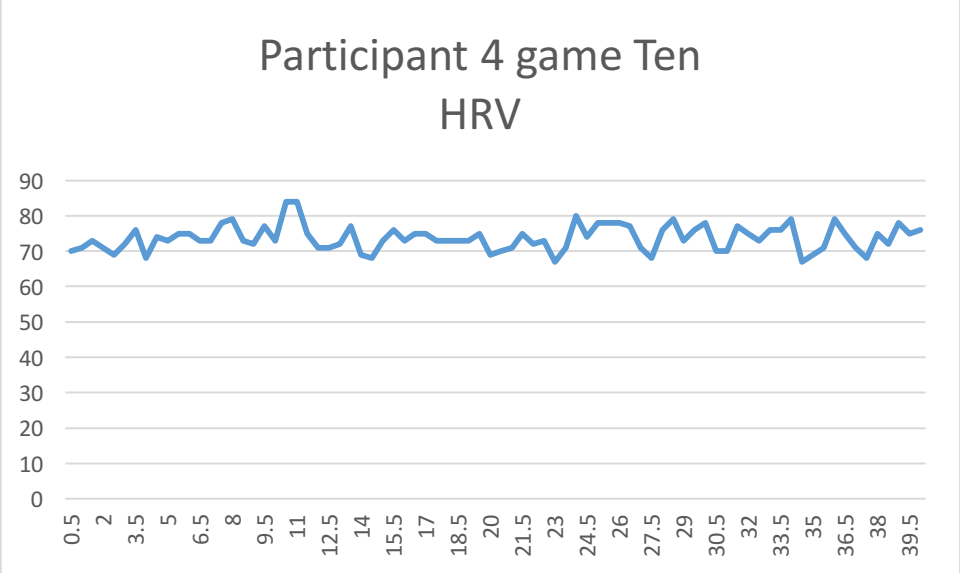
Participant 4 game Ten
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Jamal is completing his M.Eng. in the Industrial Engineering department. Jamal also obtained his B.S. in Industrial Engineering from the University of Louisville. While at the University of Louisville, Jamal was active in the community as a member of Alpha Phi Alpha Fraternity Inc. as well as serving two terms as the National Society of Black Engineers President. Jamal worked as a co-op at CEPEDA ASSOCIATES a defense contractor in Louisville, Kentucky for three separate semesters in which he performed numerous task as a quality engineer. Jamal also worked as a student worker / community leader with GE appliances at Firstbuild in Louisville, Kentucky for one year in which he provided support to all facets of the company and engaged with the community to provide a safe and efficient way to operate equipment.

Education:

M.Eng. Industrial Engineering, University of Louisville, Expected 2016
B.S. Industrial Engineering, University of Louisville, 2015

Professional Activities:

Alpha Phi Alpha Fraternity Inc. April 2015 – present
National Society of Black Engineers. October 2011-present

Advisor:

Dr. Jason J. Saleem, University of Louisville