



A Numerical Approach to Character Optimization in World of Warcraft

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Abstract

World of Warcraft (WoW), a massive multiplayer online roleplaying game (MMORPG), has for years been touted as one of the most complex, fun, addicting, and exciting games to hit the online gaming market. Released over 12 years ago, players of the game have and continue to constantly attempt to find ways to “optimize” their characters defensively and offensively. The goal of WoW is to create a character which is capable of surviving combat against bosses. This project aims to create an optimal “gear provision” strategy for players to follow in order to best increase their character’s strengths, and to consider the impact of gear on the five attributes which affect the damage a character inflicts and suffers.

This project will serve as a proof of concept for creating a gear weighting system in World of Warcraft. Through “real” and simulated data, a user will be able to quantify differentials in gear upgrades.

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1. Introduction

1.1 Relevance to Actuarial Math

World of Warcraft (WoW) is an old and very complex game. In order to properly be able to understand it, there are terminology and technical aspects which must first be defined. This section will serve as a brief introduction to World of Warcraft, as well as a crash course in the concepts of raiding, team building, gear provisioning (gearing) and character maintenance.

However, before diving into the definitions and technicalities of the game, we should define the relevancy of the project to actuarial mathematics. In actuarial math, we build models, using parameters from real data in order to make predictions for outcomes. This project will consider five parameters (to be defined more thoroughly later) and use their weighted values to predict a final statistic, Damage per Second (DPS). I hope to extend the methodology of this project into future projects in order to use, for example, different measurable health factors, such as heart rate, blood pressure, weight, and glucose and attempt to ascertain the impact of these variables on life expectancy, specifically, to identify the differential impact of each factor in order to allow consideration of advice on lifestyle changes which might have the most impact. Regarding human life expectancy, there are so many other lifestyle factors that a simple model with only a handful of factors wouldn't provide a definitive estimate sufficient to provide definitive correlations between our factors and life expectancy; however, in World of Warcraft, almost everything your character is able to do stems from five identified factors, so it is easy to measure how the changes in the factors affects the character's DPS. The ability to identify significant factors and determine the impact will ultimately allow the user to determine which

characteristics might have the most relevance in changing a character's DPS, which is analogous to changes in life expectancy based on the identified factor's impact on general health.

1.2 Concept of Raiding

World of Warcraft is a game mainly built around Raiding. "Raiding" is when a group of players (anywhere from 10 to 30) form a team and attempt to fight against a NPC (Non-Player Character), otherwise known as a "boss." Each team has an unlimited number of attempts against these bosses; the goal is to work together and kill the boss. There are three "types" of characters for raiding, tanks, healers, and "DPS." For the sake of this project, we will be looking at DPS characters, since the other classes don't have reliable data available to use to find their stat weights.

1.3 Characters, Classes and Specializations

Within WoW, you, as a player, control or pilot a character. In order to specify your character, you must choose a "Class" and then a "Specialization". There are 12 different Classes to choose from, and this could be considered comparable to choosing the manufacturer or "make" of a car. When you choose a car; however, you don't just say "I want a Hyundai", you have to choose which model of Hyundai you want based on how you intend to use it. In this example, Class is the make of car and Specialization is the model of the car you choose. Underneath each Class is a set of Specializations to choose from; just as with car manufacturers, some Classes have more and some Classes have fewer specializations. Each class has a different attributes which are weighted differently within each class. For our car, a Genesis is faster because it has more horsepower, but can't store as much cargo. Whereas, a Tucson sacrifices fuel economy for performance and storage. A company might use a fleet of differing cars based on its

business objectives, for example, sales and service. Because WoW is mainly played as a team, each team uses a mixture of characters with different classes and specializations in order to create an optimal team composition. There are a total of 36 pairs of Class and Specializations. Each Class and Specialization combination results in a character which has different abilities and utilizes different attributes in different ways.

1.4 Player Attributes (Statistics, or “Stats”)

“Attributes, often referred to simply as stats, are the basic building blocks for a character’s combat ability.”¹ In World of Warcraft, each character has three sets of stats, primary, secondary and tertiary. For the sake of this project, we will be looking into primary and secondary stats, as tertiary stats have no effect on combat ability. There are three primary stats: intellect, strength, and agility. Each character uses only one primary stat - for example, a mage uses intellect, while a warrior uses strength. These are called primary because all of a character’s abilities are affected by them; each specialization can only use one of the three, so for this project we’ll be using the term “primary” in place of intellect, strength or agility. There are four secondary stats: haste, mastery, critical strike, and versatility. Every Specialization uses all four of these secondary stats, but the effects on the character depend on the character’s Specialization. Continuing with the car analogy, think of these as similar to modifications to your car; they affect how your car performs but each stat has a different effect based on the car you drive. For example, if one of the stats was equivalent to putting a spoiler on your car, it wouldn’t have as much of an effect on performance for a pickup truck as compared to a sports car.

¹ <http://wow.gamepedia.com/Attributes>

Each stat changes each Class differently; therefore, we cannot make sweeping statements about the stats as a whole. Accordingly, we need to look into each Specialization and use numerical analysis to find out the rate of impact for each stat per Class.

1.5 Stat Weights

The rate of change for each character's abilities is different for each of the stats, therefore, we'll identify the amount of differential one stat has on a player's combat ability as its "weight." In World of Warcraft, while in combat with an enemy, you inflict damage. Damage is the amount of health you remove from an enemy, referred to as DPS (Damage per Second). The amount of damage your character inflicts directly is dependent on your character's stats. To measure the effect each stat has on your character's combat ability, we will identify the result of DPS changes per point change in each stat, and this will be referred to as the stat weight.

1.6 Gear

Each boss in World of Warcraft when beaten, generates or "drops" "loot," also known as gear. Loot is the reward for succeeding in an encounter. Each boss can only be killed once per week, and drops a limited number of pieces based on group size. For example, if you and nine other friends fight a boss, it would drop pieces of gear totaling 30% of the number of people in the group. (E.g., a boss beaten by a group of 10 people will drop 3 pieces of gear.) In addition, the equipment dropped goes to certain equipment slots (locations on the character).

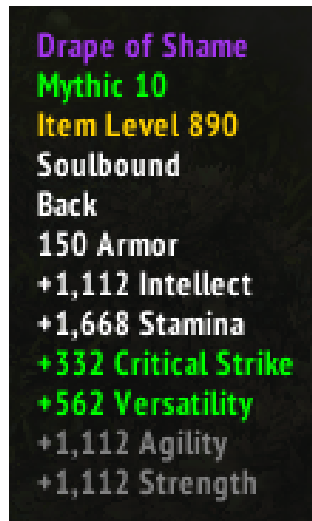


Figure 1. Example of a Piece of Gear

Figure 1 shows an example piece of gear; with values for each attribute. They greyed out attributes are not used by the character wearing this piece of gear.

Each piece of gear has a set of attributes (stats). As the character is equipped with better gear, the character gets increased or better attributes which in turn improves the combat abilities of the character. The gameplay conundrum, and one of the main factors leading into the creation of this project, is that once a piece of gear is used by a player on a character (equipped), it cannot be traded; there are no 'hand-me-downs' in World of Warcraft. This means that every time a group is deciding to whom the new loot should go, it is important to optimize distribution based on which character will benefit the most from the gear. There are many different pieces of gear each character can wear, but they are mostly shared amongst classes, so the specific 'slot' (location) the gear is in does not matter, only the gear's impact. For example, a character can wear a piece of equipment on his shoulders, hands, legs, feet; we only care about the information on each piece, since we're only comparing pieces in the same slot. (The boss drops equipment specific to a slot, and therefore, the location is not a factor which impacts this weighting). The

primary purpose of this project is to develop a way to rapidly determine gear optimization, to avoid wasting gear where it is least useful and to determine (and therefore increase) the relative value before the gear is used, and, therefore no longer available for any other character's use.

2. Project Goals

There are three main goals in this project: Gather or create relevant data to model player attribute weights, create a usable interface through which any average player can find out their desired attribute weights, and find out which Classes and Specializations benefit most from specific gear.

2.1 Data Acquisition

The majority of data will be gathered from Warcraft Logs². This is a site in which users upload combat data from each boss encounter. The site parses the data into a usable format for the everyday user. One of the goals of the project will be to create a way to pull data from the website and export it, to allow the data to be imported into an excel spreadsheet for analysis. Note that using the data in this way is legal, and even encouraged by the owner of Warcraft Logs. If the data on Warcraft Logs is not easily accessible, it will be simulated through the World of Warcraft combat simulator, SimulationCraft³.

² www.warcraftlogs.com

³ www.simulationcraft.org

2.2 Finding Stat Weights

After data has been collected, the next step is to create a model which analyzes and reports stat weights for each of the different character attributes. This will be done using Excel.

2.3 Usable Interface

One of the goals of this project is to create an interactive user interface, so any player can download the spreadsheet, put in their character's stats and then find out the weights behind each of the different gear attributes.

2.4 Item level Scaling

A character's item level is derived from the average value of gear a character is wearing. Another way to measure a character's effectiveness, in a less specific way, is to look at their item level. Each piece of gear that drops when a boss is defeated has a numerical value assigned to it; this value is the "item value", a character's "item level" is the average of the item values of all of the pieces of gear they are wearing. This project will delve into finding which Specialization, on average, benefits more or "scales better" with item value.

3. Methodology

3.1 Data Acquisition

In order to determine the impact different gear has on characters, it was necessary to attempt to collect differential data. Fortunately, a website exists which contains or creates data on every encounter between characters and a boss, but this information is not contained in one static database. To download, or "scrape" data, it was necessary to evaluate the way the

encounter data was stored on the website. In order to pull the data from Warcraft Logs, since there is no database which has it all stored, we created a program to crawl the web page to scrape the data. This program, written in python, uses Selenium and BeautifulSoup (python plug-ins) for web page table lookup, string acquisition, and parsing.

Here is an illustration of the data maintained on the website. Each set of parses is broken down by specialization, and by boss. In this data set, there are 10 different bosses:



Figure 2. List of Bosses

For each boss encounter, for all teams who fought and killed that particular boss, there is a ranking based on their DPS and Specialization:

Rank	Name	Guild	Realm	lvl	DPS	Date	Duration	Talents/Trinkets	
1	Venousback	CATASTROPHE	Twisting Nether (EU)	912	1,344,290.0	Apr 10, 2017	2:43		
2	Désaccord	Archon	Illidan (US)	911	1,344,280.0	Apr 13, 2017	3:03		
3	Whitenoise	Practice Makes Perfect	Burning Legion (EU)	912	1,321,340.0	Apr 12, 2017	2:53		
4	最後の旅程		末日行者 (CN)	909	1,312,500.0	Apr 13, 2017	3:10		
5	Dartáron	Safety Dance	Burning Legion (EU)	911	1,309,050.0	Apr 12, 2017	2:49		
6	漸行漸遠...		寒冰皇冠 (CN)	915	1,292,760.0	Apr 10, 2017	2:29		
7	쿠와야야양	Secret of Lucy	아즈사라 (KR)	911	1,290,840.0	Apr 6, 2017	2:26		
8	Paradeath	Tyranny	Shattered Hand (US)	913	1,290,400.0	Apr 11, 2017	2:32		

Figure 3. Table of Rankings

Each ranking line has a related character report, and within each report is a table of stats:

00:00:00.000

Venousback

Spec ID: 251

Str: 40490, Agi: 7529, Int: 4002, Armor: 4655, Dodge: 0, Parry: 0, Block: 0, CritM: 7537, CritR: 7537, CritS: 7537, Speed: 0, Leech: 0, HasteM: 7625, HasteR: 7625, HasteS: 7625, Avoidance: 541, Mastery: 8142, VersDmg: 1361, VersHeal: 1361, VersDR: 1361

Talents:

Gear:

Artifact:

Buffs:

Figure 4. Player Statistics from WCL Report

In order to find the stats for each of these subdatasets, we will iterate over the entire list of rankings, and for each rank in the list, we will enter the report and pull the string of stats. This will result in a set of Excel strings that look like this:

Name	DPS	Stats									
Venousback	1,344,290	Str: 40490, Agi: 7529, Int: 4002, Armor: 4655, Dodge: 0, Parry: 0, Block: 0, CritM: 7537, CritR: 7537, CritS: 7537,									

Figure 5. Stat String from Excel

Next, we will take this data and parse the data to allow comparison and data analysis.

3.1.1 Problems in Data Acquisition

While attempting to gather data from the website, there were a few problems. First, the amount of time it takes to crawl the web pages is unacceptably long for purposes of data aggregation; each webpage load takes around 1 second, and with 150,000 data points per specialization, the program would take days to complete. Second, the owner of the website purposely made it difficult to crawl the web pages (again, they are not averse to allowing their data to be used, but if it's too easy to copy data, their site could be replicated by data pirates). Additionally, within each report on Warcraft Logs, each player is assigned an identification number, which is referenced throughout the report. This identification number is essential to find the stats for each player. In order to make it difficult for his data to be "stolen", the owner of the website made these identification numbers randomized, so there is no easy way to go into each report and find the user which you entered the report with.

As a result of the identified impediments, I found a separate way to obtain data, using a simulation approach.

Although using “live” player data from encounters from Warcraft Logs was my original intention, in order to show proof of concept for this project I decided to use an alternate dataset.

3.2 Data Simulation

Luckily, World of Warcraft has a very dedicated player base. The players of World of Warcraft have created a program called SimulationCraft⁴, this program simulates player combat against a boss, and can quickly calculate DPS, over thousands of iterations.

Using SimulationCraft, which outputs a data set for each simulation, with more than 10,000 iterations, I was able to overcome the severe time constraints of data-scraping the live data for “proof of concept.” (In order to derive the actual differential benefits of equipment, I would need to successfully ‘scrape’ the data). Therefore, I modified SimulationCraft to make slight changes in each of the stat weights, and record the amount of DPS. Making the changes in the stat weights allows determination of the value of the equipment differential. I compiled the list into averages for each stat, creating the chart in Figure 6.

⁴ www.simulationcraft.org

Agility	DPS
-1500	625,914
-1350	628,887
-1200	630,368
-1050	631,332
-900	634,534
-750	637,103
-600	637,156
-450	640,415
-300	641,249
-150	644,112
0	645,548
150	646,362
300	649,803
450	651,802
600	654,434
750	655,755
900	657,208
1050	659,849
1200	660,694
1350	661,822
1500	666,333

Figure 6. Agility Scaling DPS Table

I replicated this process for 5 Classes (of the 12), and 5 stats, primary (agility, strength, and intellect) of which, each class only uses one, and critical strike, haste, mastery, and versatility.

3.3 Creating Scaling Factors from Data

In order to find a weight for each stat, we need to identify the effect that changing one point of stat has on the DPS. As such, the equation to find the value of 1 point of stat would be:

$$\text{StatWeight}(\text{Stat}) = \frac{(\text{DPS}(\text{Baseline} + \Delta\text{Stat}) - \text{DPS}(\text{Baseline}))}{\Delta\text{Stat}}$$

Where $\text{DPS}()$ is the output of the simulation average at that stat value, using the table above, an example of this would be:

$$\text{Statweight}(\text{Agility}) = \frac{\text{DPS}(0 + 150) - \text{DPS}(0)}{150}$$

Which ends up simplifying to:

$$\text{Statweight}(\text{Agility}) = \frac{646362 - 645548}{150}$$

And finally:

$$\text{Statweight}(\text{Agility}) = 5.43$$

This means that for each extra point of agility we get, we increase DPS by 5.43. Note that this result assumes a linear relationship for changes near a certain level of agility, but that the slope of the line changes as we move into different ranges within the table.

This process can be applied to all of the different stats, creating a “weighting” for them. This allows the player to determine which gear is the most valuable in terms of the mixture of attributes.

3.4 Item Level Scaling

A topic of interest to players is comparing themselves to the average player, in order to see how they should be performing. One easy way to do this is to look at a character's item level, which is an average of all of the values of pieces of gear with which the player is equipped.

I was able to identify that Warcraft Logs maintains this data, so I wrote a script to pull data from the website and record the DPS for the 50th percentile bracket, as well as the respective item value. Figure 6 is an example of what the table looks like for a few specializations. The table shows different Class and Specializations combinations, the Item level bracket they are in, and their DPS.

	DPS	DPS
CLASS-SPECIALIZATION	Item Level 870	Item Level 873
DeathKnight-Frost	394,419	429,104
DeathKnight-Unholy	269,607	302,535
DemonHunter-Havoc	395,287	434,291
Druid-Balance	372,266	409,995
Druid-Feral	319,651	338,337
Hunter-BeastMastery	386,182	429,254

Figure 7. Item Level Scaling Chart

This gives each player an idea of where they should be performing given their item level. I improved on this data by looking at the expected value of the increase in DPS per bracket, given in which bracket the character is. For example, a player in the item level 870 bracket, wanting to see how much their character will increase in damage, on average would use this formula to find their future expected value:

$$\frac{1}{15 - k} \sum_{i=k+1}^{16} X_i$$

$k = \text{bracket you start in}$

16 = total brackets you're iterating over (e.g end bracket – starting bracket)

$X_i = \text{DPS increase at bracket } i$

This will find the average expected DPS of your character, given you are at entry k.

4. Results & Implementation

4.1 Excel Stat Weights

Using the simulated data, we now have derived stat weights for each of the simulated classes. In order to make this useful, it needs implementation and reliability; in order to achieve this, we implemented the data into an excel spreadsheet with adjustable values.

Choose Class from Dropdown		Input your stat weights (Rounded to the nearest 150)	
Class		Your Stats	Weight
Hunter - Marksman	Primary	600	14.81
	Crit	750	16.96
	Haste	1050	12.80
	Mastery	600	15.00
	Versatility	600	12.74

Figure 8. Excel Sheet with Dropdowns

4.1.1 Finding Stat Weights for Your Character

I imported a condensed version of the simulated data, taking averages at each of the stat ranges:

agility	DPS
-1500	625914
-1350	628887
-1200	630368
-1050	631332
-900	634534
-750	637103
-600	637156
-450	640415
-300	641249
-150	644112
0	645548
150	646362
300	649803
450	651802
600	654434
750	655755
900	657208
1050	659849
1200	660694
1350	661822
1500	666333

Figure 9. Condensed Simulated Data Stat Weights

From this spreadsheet there are a few simple steps to find the stat weights for your character:

1) Choose your specialization from the drop down menu:

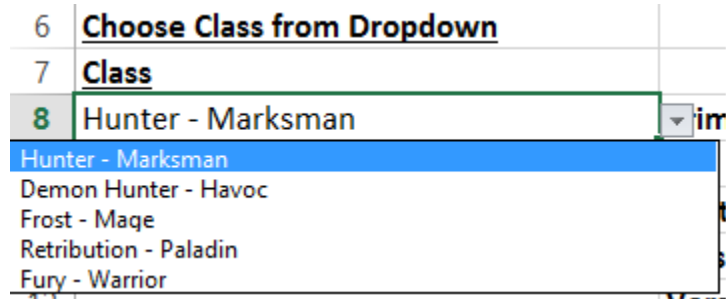


Figure 10. Specialization Dropdown Menu

2) Input your stat weights (rounded to the nearest 150)

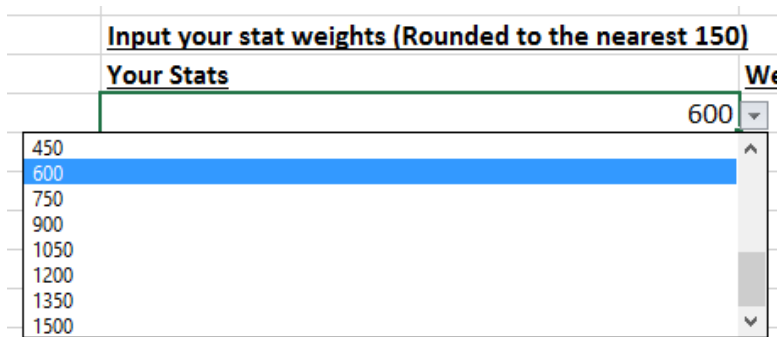


Figure 11. Your Stats Dropdown Menu

3) The table will output your stat weights.

<u>he nearest 150)</u>	
	<u>Weight</u>
600	14.81
750	16.96
1050	12.80
600	15.00
600	12.74

Figure 12. Stat Weight Column

4.1.2 Comparing Pieces of Gear

Now that we have stat weights, we can use these to compare pieces of gear, and find out how much of an upgrade a piece will be. In the second sheet in the Excel File is a gear comparison tab.

In order to compare two pieces of gear, you will need the stat values of each. Within the spreadsheet, on the “Gear Comparison” sheet, plug in the values of the pieces of gear, and the sheet will output the upgrade percentage of the piece of gear.

	<u>Gear 1</u>	<u>Gear 2</u>
Primary	4	4
Crit	3	4
Haste	4	3
Mastery	3	3
Versatility	3	3
Total Value	244.514	248.676
Upgrade Percent:	2%	

Figure 13. Gear Comparison Sheet Example

Now that each character has used this to find the upgrade from their piece of gear, the group leader can use this information to give the gear to the player who it's the biggest upgrade for.

4.2 Item Level Scaling

As previously stated, Item Level is the average value of the equipment a character is wearing. The Item Level Scaling data sheet is more empirical than interactive. Due to how the data is presented on Warcraft Logs, the item level 'brackets' are increases in intervals of 3 item levels. From this sheet we can make a few claims about some of the specializations, as well as the set of DPS classes as a whole.

A reasonable claim we can make is that some class-specialization combinations scale better with gear than others. We can look to the average increase in DPS per bracket:

SPECIALIZATION	AVERAGE INCREASE PER BRACKET CHANGE
DeathKnight-Frost	15259
DeathKnight-Unholy	13006
DemonHunter-Havoc	13677
Druid-Balance	14197
Druid-Feral	12491
Hunter-BeastMastery	14630
Hunter-Marksman	11001
Hunter-Survival	14046
Mage-Arcane	16672
Mage-Fire	13397
Mage-Frost	13948
Monk-Windwalker	14982
Paladin-Retribution	13737
Priest-Shadow	15451
Rogue-Assasination	13370
Rogue-Outlaw	13066
Rogue-Subtlety	13623
Shaman-Elemental	14209
Shaman-Enhancement	14812
Warlock-Affliction	14298
Warlock-Demonology	13943
Warlock-Destruction	13860
Warrior-Arms	14208
Warrior-Fury	10639
Average	13390

Figure 14. Table of Average DPS Increase per Item Level Increase

Certain class-specialization combinations stand out compared to the average. For example, Arcane Mage, Shadow Priest, and Frost Death Knight.

We can determine that item level doesn't linearly scale; because as item level increases, the change in DPS is not constant.

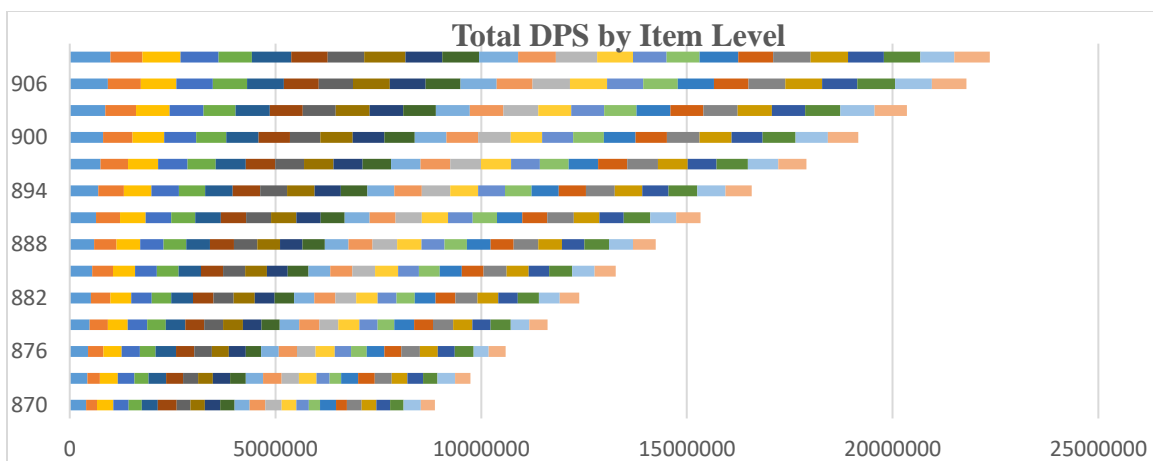


Figure 15. DPS by Item Level Chart

This chart is a chart of all of the DPS classes, it shows the scaling from item level bracket to item level bracket. Each different color is a different specialization; this is a graphical way to see the changes in damage. Just looking at the chart, it's relatively apparent that the total increase between each level increases.

6. Conclusion

I was able to achieve the majority of this project's goals. Although this project's original intent was to use live data to find stat weights for characters, we used simulated data to create a proof of concept on using live data to derive stat weights for characters. Through the use of simulated data, we now have a way for any player to figure out their stat weights for their character. The potential best benefit of this project is its ability to be applied to competitive groups. Using these stat weights, along with a group leader's ability to decide where each piece of gear is awarded, allows a group to optimize gear distribution. This project has demonstrated immediate benefit in my own guild group where we utilized the spreadsheet to compare gear between two different players. Comparing their current piece of gear to the new one that

dropped, and using their stat weights from the spreadsheet, we were able to find that it offered a larger upgrade (8% over 5%) for one of the players.

Even though we used simulated data in order to create a proof of concept for a live data, this simulated data set has real, in-game application. Once Warcraft Logs data is more readily obtainable, this project can easily utilize that data.

7. Acknowledgments

I would like to take time to acknowledge a few people who have helped make this project a success. First, I'd like to thank Jon Abraham who consistently helped with project ideas and editing and model help. I'd also like to thank the following people:

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Lambert Wang, for helping code the data extraction tool I used.

I'd also like to thank WPI for being an amazing school for 4 years!