Introduction

The world of Pokémon began in 1995 with the pair of games Pokémon Red and Green. For Western audiences, the latter game would become known as Pokémon Blue. These two games introduced a unique system of turn-based that continues to define the franchise of Pokémon games. Numerous other games have attempted to copy the Pokémon battling format, but none have been able to equal its widespread appeal and dedicated player base. With each successive iteration, new items, Pokémon types, and of course new species of Pokémon are added to the Pokémon lexicon. As a result the world of Pokémon has continued to grow and evolve into one of the largest video games franchises to date. The most recent iteration of Pokémon games, Pokémon Sun and Moon, have continued Pokémon's commercial and historical trend of turning profits while adding layers to an already complex system of battling.

Since 2011 the program Pokémon Showdown has offered a simplified version of Pokémon games. This simplified version allows players to exclusively battle one another, replicating the most recent iteration of the Pokémon games in the process. This has allowed players to hone and test their Pokémon battling skills through the years. With well-over 20,000 daily registered users and counting, this program has become the go-to program to test and practice Pokémon battling strategies in the ultimate pursuit of becoming the very best that no one ever was.

However, before any formal analysis of Pokémon battling is discussed the battling system must be rigorously detailed for laymen and theorists alike.

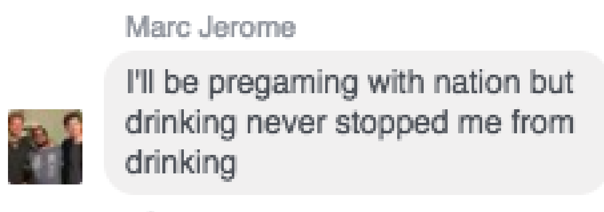

Figure 1: Inspiration

First and foremost, each Pokémon battle occurs exclusively between two players. Each of the two players has a team composed of six Pokémon. For the purposes of analysis teams with duplicate Pokémon will not be considered, namely because such teams are not allowed in ranked battles. As such, teams are composed of six distinct Pokémon. Depending on the battle format, the team of six Pokémon is either dictated by the player or randomly assigned. Regardless of the battle format, each turn each player simultaneously make a decision for the Pokémon they have on the field. The decisions are then executed. The order of play is decided by comparison of the selected moves. Priority is given first to priority moves and then, if neither player selected a priority move for the turn, by a comparative assessment of the two Pokémons' speeds.

The potential moves Pokémon are able to execute have a wide variety of effects. This will be detailed later however. Regardless of the damage or effects of the executed moves, once a player's Pokémon loses all of its health, an event referred to as fainting, the player must switch into another Pokémon. If a player has no other Pokémon to switch into, the battle ends. As would be expected, the player whose Pokémon have all fainted loses the battle. Consequently the player who eliminates all of their opponent's Pokémon wins.

Furthermore, each Pokémon has at most four possible moves to chose from during any turn of a battle. Whenever a player has at least two Pokémon that have not fainted, they have additional choice to switch into another Pokémon. Doing so counts as the player's action for the turn. As a result, players almost always have five different choices to make each turn.

There are still a number of other details that are relevant to consider beyond those already mentioned. Namely, while some information is fixed during the battle -such as the opposing players team composition- some variables of interest are case-specific. These include what moves an opposing Pokémon has already used, and consequently revealed, along with a given Pokémon's held item, its ability, and a slew of other variables. However, similar to the different type of moves a Pokémon can chose from, these points will be detailed in the methodology section.

That being said, to formally analyze Pokémon battling the game itself must be formally denoted in game theoretic terms. This will aid in both describing the game and in highlighting its complexity. With this in mind, it bears noting that there are only two outcomes to any battle: One player wins and the other loses. Because of this, Pokémon battling is by definition a zero-sum game. However, it is important to note that there some distinctions between how a player wins or loses a game. Though the game ends when all of the Pokémon on one team have fainted, any player has the choice to forfeit the game any time before this occurs. Thus, the two ways to win or lose a battle are either by forfeiture or by having all of their Pokémon faint; this latter outcome is referred to as a "normal" game. Additionally, there is the potential for a game to result in a draw. However, draws result in a neutral payoff as neither player raises or lowers their ranking after a draw.

Within the scope of game theoretic terms, it is vital to note that each player is able to see all past decisions made over the course of a battle, and that battles typically last a number of turns. Speaking to the former point, players are able to recall not only their past decisions but also those of their opponent, including how much damage was done by a specific move during a previous turn. As this information is available at any time during the battle, Pokémon battling is a perfect recall game. Furthermore as each game is composed of a sequence of turns, Pokémon battling is also a sequential game.

The points noted on information allude to a unique trait of Pokémon battling that further details the type of game Pokémon battling is: An incomplete information game. Though the extent of incompleteness is format specific, each player is given limited information about the opposing player's team at the beginning of the battle. After each turn, players learn not only the different moves each opposing Pokémon has, but also their abilities, held items, and sometimes what other Pokémon compose the opposing team. Generally speaking, there is almost always new information revealed each turn.

However, the extent to which player strategies are revealed from revealed information is an open topic of discussion, both in this study and in current game theory literature. Naturally, the analysis of such a topic relies upon at least one apriori assumption, namely that player strategies are revealed by their past decisions. However, whether player strategies are rational and consistent is another matter entirely; nonetheless, it is important to note that incorporating such information into players own decision-making complicates analysis and is a central topic in analyzing Pokémon battling.

Taken together, Pokémon battling is a special case of a sequential, zero-sum two-player game with incomplete information and perfect recall. As Pokémon battling lends itself to a discussion of imperfect information, it is all the more vital to consider the role of decision making within the context of sequential games. As a great deal of game theory literature has explored such topics, and this work will attempt to expand upon it. However, it is vital to note that this study will not do so using expansive game trees or comparison of payoffs.

Game theoretics aside, there are also important computational notes to detail. In this regard, initial computations and analysis focus on the distributions of turn length, i.e. the length of games played when one player forfeited or had all of their Pokémon faint and the corresponding distribution of game lengths. After these distributional computations, I categorize moves by their type, specifically whether a specific move is damaging or what is referred to as a "setup" move. After this categorization I gauge the effectiveness of using specific moves on the experimental probability that using such move corresponded to a winning outcome.

Overall I explore how information gathered turn-by-turn feeds into the decision-making process of Pokémon battling. By incorporating tenants of behavioral economics and game theory, I hope to analyze and highlight phenomena that occur in the Pokémon battling simulator Pokémon Showdown. However, even more specifically I will continue the recent trend of 'Big Data' analysis to explore macro trends in player's decision making process.

Literature Review

Scant rigorous or academic research has been conducted within the scope of Pokémon-related topics. The most frequent publications have focused either on Pokémon as a cultural phenomena or have been official strategy guides for the various Pokémon games published by Nintendo affiliates. Importantly, these strategy guides do not detail Pokémon battling strategies, although they do detail the numerous Pokémon species, items, and moves available in each game. It comes as no surprise then that the Pokémon strategy guides do not formally detail Pokémon battling strategies or use of game theoretic terminology. That isn't to say that there aren't publications focusing on Pokémon battling strategies.

Academic papers that focus Pokémon battling have developed and analyzed algorithms to simulate Pokémon battling and engage in Pokémon battling against human players in the program Pokémon Showdown. The first paper of this kind gives a rudimentary background on Pokémon battling and focuses explicitly on 1v1 battle simulations (Gildardo 2013). However, in a detailed analysis of one particular one-on-one scenario the author is singularly-minded, and does not consider other potential variants on Pokémon ability and item match-ups. In this regard, Gildardo's article does not go into great detail on the many variants of Pokémon battling, most notably through the exclusion of teams of more than one Pokémon.

This point notwithstanding, since this publication there has been one other notable publication that focuses on Pokémon battling. This publication focuses on the creation and analysis of algorithms within the context of Pokémon battling. Along with including teams of six, the article gives greater detail on battling strategies while incorporating comparative analysis of the different algorithms used to play against human opponents (Ho et al. 2016). Though the paper focused on what is currently a previous iteration of Pokémon Showdown, the iteration of Pokémon Showdown is fundamentally the same as that of the data used in this study. Nonetheless, the paper did have its own shortcomings as well. Namely, the algorithms used would never select a move whose type would be not very effective against the opponents fielded Pokémon. This point will be detailed later, but needless to say such a decision is not always the preferred one.

Furthermore, on the subject of different versions of Pokémon Showdown, relevant documentation of the past iterations of Pokémon Showdown are available at the program's website: http://pokemonshowdown.com/. The website for Pokémon Showdown provides a hub for information ranging from Pokémon battling basics to specific battle format descriptions. Similar to all information mentioned thus far, replays and ladder ranking are available publically. Furthermore the site provides Pokémon usage statistics and a damage calculator for aspiring Pokémon battlers.

As noted previously, game theory vernacular has not entered into discussions on Pokémon battling strategies, at least in any formal setting. Applying such concepts to the context of Pokémon battling offers a formal foundation to discuss strategies and test hypotheses. In this regard, there are three main areas of game theory that intersect in the analysis of Pokémon battling. These three areas of interest include the interpretation of Pokémon battling as a zero sum game, the role of incomplete information, and the implications of Pokémon battling as a non-cooperative game. These three topics actively influence the decision-making process associated with Pokémon battling.

A central factor involved in the decision making process as it relates to game theory is the role of information, specifically how players incorporate information revealed each turn into their strategies. As information is revealed each turn, including the four moves an opposing Pokémon has, its ability, held item, along with what other Pokémon are on the opposing team, it is vital for players to determine if the information they just received is relevant. Furthermore, players need to decide if the information provides any insight into their opponent's strategy. Overall, this speaks to Pokémon not being a perfect information game. As such, it is not possible to apply Zermelo's theorem, though its negation provides insight as to the possible existence of a winning strategy (Schwalbe et al. 2001).

An especially interesting addition to the analysis of incomplete information in Pokémon battling is the topic and implications of asymmetrical information. In this regard, the concepts of sunk costs and signaling may enter into the equation. Especially for the Random battle format, each player is given minimal information at the onset of the game. And while each turn, players both gain information, they may receive new information at different rates. The implications of this point may provide insight into specific strategies, and is a point of future analysis.

This being said, concepts from game theory are not the only relevant ideas for analyzing Pokémon battling. In the context of exploring the frequency of players switching Pokémon will necessarily invoke concepts from from behavioral economics as well as game theory. Relevant to the field of behavioral economics, the concept of “keeping doors open” applies as well as post-op payoff analysis. The concept of “keeping doors” open is explored in Chapter 6 of Ariely’s work Predictably Irrational, giving a semblence of what the expected results may be. In the context of Pokémon battling, players may decide to preemptively switch Pokémon in the hopes of having that Pokémon later in the battle. Via application of Ariely’s experimental results players may prefer to keep options -availability of certain Pokémon- open, even if doing so incurs costs and/or reduces their chances of winning. Whether this adversely influences the players’ outcomes is another point of inquiry.

As an ending point of interest, taking into account opposing players’ strategies as deduced from revealed information rubs against issues related level-K thinking. To elaborate further, knowing that a player is likely to repeat the same decision made the previous turn, players may be able optimize their decision by presuposing what decision their opponent is going to make. However, if the opposing player decides to incorporate that very assumption into their own decision, they may arrive at a vastly different outcome than would be expected. Furthermore this outcome may even be suboptimal for both players. That being said, the inclusion of level-k thinking is closely aligned to recent behavioral game theory literature. A central finding of this literature has emphasized the role of iterated reasoning, which essentializes player adaptation to other players’ decision making (Wunder et al. 2011). Notably this will be a point to consider and incorporate into the analysis of Pokémon battling in a game theoretic framework.