A Big Data Analysis of Pokémon Battling

A Thesis
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I want to thank a few people.

Preface

This is an example of a thesis setup to use the reed thesis document class (for LaTeX) and the R bookdown package, in general.

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Abstract

The preface pretty much says it all.

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Dedication

You can have a dedication here if you wish.

Chapter 1

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.

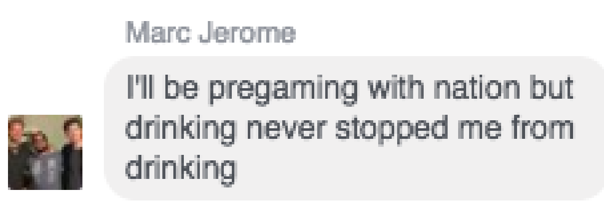

Figure 1.1: Inspiration

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 randomly assigned or dictated by the player. The two formats being considered in this study -random battles and overused- provide an example of each respectively. As a point of note, only battles in the 'Anything Goes' category allow any Pokémon to be used, including duplicate species within a player's team.

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. However, it is vital to note that this study will not do so using expansive game trees or comparison of payoffs. Namely this is done due to computational limitations. A detailed explanation as to the inability of fully detailing normal form games and payoff functions in the context of Pokémon battling is found in Appendix A.

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 the decision-making process involved in Pokémon battling. By incorporating tenants of behavioral economics and game theory, I hope to highlight not only the experimental probabilities of winning associated with specific move sets, but also analyze how and why such events occur. More specifically I will continue the recent trend of ‘Big Data’ analysis to explore macro trends in player's decision making processes by using *all* of data contained within four months of Pokémon Showdown battlelogs spanning 2015. In doing so I hope to answer two main questions: What factors influence the liklihood of winning a Pokémon battle, and are these findings generalizable across battle formats?

1.1 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, insomuch as literally focusing only on one-on-one Pokémon battles. Furthermore, Gildardo's subsection detailing Pokémon battling does not consider other potential variants on Pokémon abilities or item pairings. 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 Pokémon.

This point notwithstanding, since Gildardo's 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; the article additionally goes into 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.

Chapter 2

Methodology

The data used is a compilation of battle logs taken from the Pokémon Showdown servers. Each battle log is stored as a .json file. The data spans across four months of the year 2015. The four months are March, June, September, and December. There are no lapses in the monthly compilations of the data, i.e. none of the daily data entries are empty. Overall, there were no dramatic overhauls done to Pokémon battling formats or the overall system for the data used in this study. However, some minor adjustments were made and such adjustments are publically documented.

Only ranked games are included in the dataset. Ranked battles are battles that count towards a players global ranking in Pokémon Showdown. For each battle, players stand to gain or lose ranking points depending on whether they win or lose the battle.

Specific Pokémon usage statistics are found in a subsidiary website. The usage statistics track the frequency of use for specific Pokémon, items, abilities, and a host of other relevant variables for Pokémon battling. On top of deriving experimental probabilities based on specific moves, probabilities will be derived that are specie-specific. Along with this, regressions include the combination of both specie and moves, at least for moves that can be learned by more than one Pokémon.

A number of links redirect users to the host site of this game: Smogon University. This website offers a wide variety of resources, similar to those found at the Pokémon Showdown website. Most importantly the Smogon forums are a prominent site for discussion of Pokémon battling strategies.

2.1 Pokémon Battling Basics

The Pokémon battle starts with Pokémon being sent out. For the purposes of the data used, one Pokémon is sent out for each opponent, totalling two Pokémon being out at any given time. Following this, each Pokémon has 4 moves to choose from, along with the option to switch to a different Pokémon (when applicable). After both players make a decision, the moves are weighted for priority and speed to determine the order of play. If both players decide not to switch one Pokémon will attack the other, after which the next Pokémon will do the same if it has not fainted. After each move has been executed the turn ends and the process is repeated. When one of the Pokémon faints, the player whose Pokémon fainted will be prompted to select another Pokémon from the bench. The first player to lose all of their Pokémon loses the battle.

However, before the nitty gritty details are explained it is important to make a concession. The entirety of the Pokémon battling system -even that used in the data- is not included in this analysis. The number of cases that deviate from the rules detailed below are either not included in the competitive format, or are generally inconsequential to the scenarios and strategies considered in this study.

2.1.1 Battle Formats

The data used for this study include two different Pokémon battling formats. The two formats are known as Over Used and Random Battles, abbreviated as OU and Randbats respectively. Both formats have teams of six Pokémon and only allow one Pokémon to be out at any given time. While both battle formats are subsets of what are known as single battles, each has their own unique spin on the Pokémon battling format.

Random battles are the most frequently played format. In this format, neither player decides their initial team compositions. This means players cannot decide the species composing their team nor the move sets of each specie on their team. Instead, the Randbats format uses an algorithm to determine team compositions. It is important to note that there are restrictions to the Randbats format that center around team composition and move composition for specific Pokémon. This restricts teams to have six distinct Pokémon per team, while still allowing the same Pokémon and move sets to be found on opposing teams but not within one player's team.

By contrast the OU format includes team composition. By including team composition, players are able to decide what Pokémon to include on their team, the moves of each Pokémon, and other factors such as held items and abilities. However, there are still some restrictions placed on players. Specific species of Pokémon are barred from use, notably Pokémon classified as "Ubers" that include a large portion of legendary and mega-Pokémon. Additionally certain "hidden" abilities are restricted, limiting the possible Pokémon abilities a specific species may use for a given format.

2.1.2 Pokémon Types

Typeage is a unique characteristic to Pokémon battling. Currently there are 18 distinct types. These include normal, fire, water, electric, grass, ice, fighting, poison, ground, flying, psychic, bug, rock, ghost, dragon, dark, steel, and fairy. Both moves and Pokémon are given a type attribute, though moves are only one type. And While a move may only be one of the 18 types, a Pokémon can be at most two different types at once.

However, some of these combinations are not found in Pokémon. From the initially possible 171 Pokémon type combinations, 18 choose 2 plus 18 monotypes, there are actually only 133 types that a players may encounter or chose from (as 38 type combinations had not yet been used during 2015). It is also worth noting that some Pokémon are able to change type during a battle, but for the purposes of analysis these Pokémon will be considered after-the-fact.

The typeage of each Pokémon influence not only the potential weaknesses of each Pokémon, but also the amount of damage that type-specific moves are able to do. Each Pokémon has at least one and at most two types. If a Pokémon uses a damaging move whose type corresponds to type of the Pokémon that used it, that Pokémon gets a same type attack bonus, abbreviated as a "stab" bonus. This causes the move to do 50% more damage, potentially 100% if the Pokémon also has the ability Adaptability.

2.1.3 Pokémon Attributes

Generally, there are a number of factors that are specific to each Pokémon. Some of these factors are considered static, meaning that they do not and cannot change over the course of the battle. These types of factors are defined as "Fixed" attributes. However some factors -such as the stats of a Pokémon- that are fixed at the beginning of the battle *can* change over the course of a battle. There are also a number of factors that are able to generally change over the course of a battle. Such factors, by constrast, are defined as "Variable" attributes. The terminology is largely taken from Ho et al. for ease of translation and applicability. The attributes are detailed in the order given.

2.1.4 Pokémon Fixed Attributes

Fixed attributes include the typeage of a Pokémon, the four moves each specie Pokémon has, the item the Pokémon holds, the Pokémon's ability, the level of the Pokémon, and the Pokémon's baseline stats. However, there are exceptions to the rules for each of these attributes except for the level of the Pokémon. Every fixed attribute and its respective exception(s) will be considered in order.

First and foremost is the typeage of a Pokémon, detailed previously. However, one possible method for a Pokémon to change its type is specific to a Pokémon's ability. Both Protean and Color Change are abilities that are able to change a friendly Pokémon's typeage. The former ability changes the Pokémon Kecleon's type to that of the move that affected it, whereas the latter ability turns its type into the typeage of the move that just was just used by the Pokémon Greninja. These two abilities are specific to Kecleon and Greninja specifically. Furthermore, there are moves that able to make the opponents Pokémon into a water, grass, or ghost Pokémon -on top of their previous typeage- if they use the moves soak, forest's curse, and treat-or-treat respectively.

Each Pokémon's set moves are also fixed during a battle. The exception to this occurs when a Pokémon runs out of power points -denoted as PP- for all of its four moves, at which point it is only able to use the move struggle. Every move has a set limit to the number of times it can be used, though the number of times a move can be used varies across the set of moves. The struggle is real.

Pokémon are able to hold one item at the beginning of the match. Pokémon may also lose their held item either by being hit by the move Knock-off, which knocks the opponent's Pokémon's item off, or by using their held item. Held items are able to be consumed for a one-time effect. This scenario often includes the consumption of berries, which offer a variety of different effects to the Pokémon holding it. For example, if a Pokémon is given a status condition -a condition detailed in the following section- from an opposing Pokémon while holding a Lum berry, the berry will be consumed and the Pokémon's status condition will be cured. This example highlights an important characteristic of some held-items: Some items may only be used once and are discarded after their initial use.

Similar to items, a Pokémon can only have one ability at a time. However, by contrast to a Pokémon's held item a Pokémon always has an ability. Nonetheless, Pokémon may have their ability swapped with another Pokémon's. This scenario only occurs a Pokémon makes physical contact with Yamask or Cofagrigus, at which point its ability is swapped with Mummy. Mummy will only change a physically-attacking Pokémon's ability; it has no other effect.

The level of a Pokémon varies between one and one-hundred. The higher the level, the better the baseline stats for a given Pokémon, specifically in comparison to lower levels of that given Pokémon. Baseline stats are divided into six categories. These categories include (baseline) health, attack, special attack, defense, special defense, and speed. There is further nuance with the inclusion of Pokémon natures and Individual Values, or IVs. These factors influence the base stats of each Pokémon. However due to the sheer number of trivial combinations of IV spreads and nature choices, these two factors will not be a pivotal aspect to the framework and analysis of Pokémon battling. Nonetheless, the votatility of these baseline stats will be considered as a variable attribute.

2.1.5 Pokémon Variable Attributes

Variable Attributes include boosts or reductions to a Pokémon's baseline stats, the status condition of the Pokémon, the volatile status of the Pokémon, the current health of the Pokémon, and whether the Pokémon is currently active.

The former-most attribute directly influences how effective an active Pokémon is able to be in battle. Pokémon are able to learn and use moves that can boost their own status or ones that reduce their opponents. However, these moves are only able to influence a Pokémon's attack, special attack, defense, special defense, or speed. For example, the move Swords Dance raises its users attack status so long as the Pokémon remains active. The move may be used multiple times, but is only effective until it boosts or lowers its target's baseline stat by 3 or 1/3 respectively.

Status conditions are composed of a variety of statuses. Pokémon that suffer a status condition are either burned, frozen, paralyzed, poisoned, badly poisoned, or have fallen asleep. A Pokémon can only suffer from one status condition at a time, although a Pokémon can suffer from multiple status conditions if it overcomes the first condition. Each of these statuses is distinct, though there are similarities between being poisoned or badly poisoned. A Pokémon that is just poisoned will take damage equal to 1/8th of its maximum HP at the end of each turn. By comparison a Pokémon that is badly poisoned takes n/16th of its maximum HP at the end of the nth turn the Pokémon has been badly poisoned. A Pokémon that is poison-type or steel-type is unable to be poisoned in any form, and if a Pokémon has the ability Poison Heal it is healed 1/8th of its maximum HP at the end of each turn.

Is a Pokémon is burned it takes 1/8th of its maximum HP in damage at the end of the turn. This has recently been changed to 1/16th of its maximum HP per turn, but this is just a passing point of note. Regardless of the amount of damage done to the burned Pokémon, the burned Pokémon's physical attacks do half damage. The exception to this rule is if the affected Pokémon has the ability Guts. A fire-type Pokémon cannot be burned.

In a similar vein to being burned, a paralyzed Pokémon has its speed reduced to 1/4th of its baseline speed. Furthermore, a Pokémon that is paralyzed has a 1/4 chance of not being able to move during its move. This event is referred to as being "fully paralyzed". Furthermore, electric-type Pokémon are unable to be paralyzed, and if a Pokémon has the ability Lightning Rod it's special attack is boosted by 1.5 its base level. Additionally, ground-type Pokémon cannot be paralyzed, just as they are not affected by electric-type moves.

A Pokémon that has fallen asleep is unable to use its moves except for the moves Snore and Sleep Talk. A Pokémon falls asleep for one to five turns. However, if a Pokémon purposely puts itself to sleep using the move rest, it is asleep for exactly two turns. If a Pokémon has either of the abilities Vital Spirit or Insomnia it cannot be put to sleep.

Lastly, there is the status condition of being frozen. Similar to previous typed statuses, ice type Pokémon are immune to becoming frozen, as are Pokémon with the ability Magma Armor. There is no set number of turns that a Pokémon can be frozen, but if a frozen Pokémon is hit by fire-type moves or the move scald is thaws out and is no longer frozen.

Volative statuses are similar to status conditions, except that the volatile status will be negated by switching out the affected Pokémon, if applicable. Similar to status conditions, a Pokémon can only be affected by one volatile status at a time. Another important point to consider is that a Pokémon can suffer from both a volatile status *and* a status condition. That being said, the most common form of volatile status is confusion. A Pokémon is confused for one to four turns, during which time the confused Pokémon has a 50% chance to hurt itself instead of executing its move for the turn. A Pokémon may also be encored, meaning that it has to use the same move it just moved for 3 turns. Additionally a Pokémon may flinch if hit before executing its move for the turn.

Only currently active Pokémon are able to execute moves. Likewise, only active Pokémon may be damaged. Beyond this there is not anything else to detail in regards to the current health and activity of a Pokémon that is exclusive to variable attributes.

2.1.6 Environmental Variables

There are one class category to detail that is relevant to the analysis of Pokémon battling This category is the role of the environment in battling and is a central focus of the analysis of Pokémon battling. Though related to the different types of moves and abilities a Pokémon has, including both fixed and variable attributes, the environment is not specific to any one move, ability, or specie of Pokémon and as such must be highlighted separately from the previous attributions.

The most prominent environmental variables to consider are what are referred to as “set-up” moves. These moves include Stealth Rock, Spikes, Toxic Spikes, Sticky Web, Light Screen, and Reflect. The latter two are different from the rest of the set-up moves in that they only last five turns, eight is the user was holding Light Clay when the move was used. When these moves are employed, the active Pokémon’s special defense and defense are raised by one stage -or is increased by 1.5- respectively between Light Screen and Reflect.

The former four set-up moves are a focal point of analysis and are in a category of moves known as entry hazard moves. These moves are of particular note because they can last for the entirety of a given battle. Once these moves are used, only certain moves or switches are able to eliminate them. Generally, using the move rapid spin or defog will eliminate the entry hazards, along with causing other effects. However, if a Pokémon uses defog both their and their opponents entry hazards will be eliminated, whereas rapid spin only eliminates entry hazards affecting the users team.

Both Stealth Rock and Sticky Web can only be active once during a battle -unless previous uses of either are eliminated by methods previously noted. However, each have dramatically different effects. Specific to the latter, Pokémon that enter the field after Sticky Web is employed have their speed lowered by one stage -or 2/3rd their baseline level. This only applied to grounded Pokémon however, or non-flying type Pokémon. By contrast, Stealth Rock will damage any Pokémon that enters the field after it is used. The amount of damage done to the Pokémon depends on the type effectiveness of rock-type moves, as Stealth Rock is a rock-type move. In ascending order, Stealth Rock will do 3.125%, 6.25%, 12.5%, 25%, and 50% of the affected Pokémon’s maximum health for type effectivenesses of 0.25x, 0.5x, 1x, 2x, and 4x respectively.

Similar to Sticky Web, spikes only affect non-flying type Pokémon. However, spikes will inflict damage to Pokémon that switch in instead of afflicting them with a volatile or status condition. The amount of damage is dependent upon the number of layers of spikes active on the field. Spikes may be applied a maximum of three times. One layer of spikes will damage the opposing Pokémon by 1/8th of its maximum HP, while two layers will deal 1/6th, and three layers will do 1/4th of the opposing Pokémon’s maximum health.

Lastly is toxic spikes that, just like spikes and sticky web, only affect grounded Pokémon. However, toxic spikes are able to be applied two times. The first layer of toxic spikes will poison opposing Pokémon that switch in, while two layers of toxic spikes will badly poison Pokémon that switch in (that is if the Pokémon that switches in is able to be poisoned). Just like most other entry hazards, toxic spikes only affects grounded Pokémon.

2.2 Model Specification

As Pokémon battles have only two outcomes, we may estimate the probability of winning using a standard probit model. Let the y-value vary between 0 and 1, where 0 denotes a lose and 1 denotes a win for a Pokémon battle. Let us consider estimating whether using entry hazard moves results in a higher chance of winning a Pokémon battle.

We begin by defining the variables. Let x be the number of uses of spikes, y be the number of uses of toxic spikes, z be the number of uses of sticky web, and w be the use of stealth rock. However, as variables x through z are able to be used more than once, there is the possibility that repeated use of these moves leads to diminshing returns. Hence for these variables we include a squared term for variables x through z. Letting p be the probability of winning a Pokémon game, and letting ϵ denote the error term, we have:

$$p = \alpha + \beta_1 x + \beta_2 x^2 \gamma_1 y + \gamma_2 y^2 \delta_1 z + \delta_2 z^2 \eta w + \epsilon$$

One of the first tests to conduct is comparing the theoretical values of α with its experimental value. Theoretically, players should have equal probability to win or lose a battle when no information is added about their decisions, so $\mathbf{E}(\alpha) = 0.5$.

Furthermore, this model does not include interactions between entry hazards, which is important both for experimental validity and as a method to cross-validate the experimental results.

There are also moves that are exceptionally powerful compared to other damaging moves. These moves take a variety of forms, either by causing the user to 'charge up' for one round in advance, lose their next turn to recharge, or by having comparatively low accuracy. Such moves may be considered risky for a number of reasons. To see if using such moves adversely affect player outcomes, a similar probit model will be used and subsequently tested.

In addition to this, the variety of different volatile and status condition moves will be included in a separate probit model. Then, after statistical significance is tested, a separate probit model will be used and tested that includes the high damage moves, status moves, and entry hazard moves with a number of different interactions included to test for robustness.

Chapter 3

Tables, Graphics, References, and Labels

3.1 Tables

In addition to the tables that can be automatically generated from a data frame in **R** that you saw in [R Markdown Basics] using the `kable` function, you can also create tables using *pandoc*. (More information is available at `http://pandoc.org/README.html#tables`.) This might be useful if you don't have values specifically stored in **R**, but you'd like to display them in table form. Below is an example. Pay careful attention to the alignment in the table and hyphens to create the rows and columns.

Table 3.1: Correlation of Inheritance Factors for Parents and Child

Factors	Correlation between Parents & Child	Inherited
Education	-0.49	Yes
Socio-Economic Status	0.28	Slight
Income	0.08	No
Family Size	0.18	Slight
Occupational Prestige	0.21	Slight

We can also create a link to the table by doing the following: Table 3.1. If you go back to [Loading and exploring data] and look at the `kable` table, we can create a reference to this max delays table too: Table **??**. The addition of the `\label{tab:inher}` option to the end of the table caption allows us to then a make a reference to Table `\@ref(tab:label)`. Note that this reference could appear anywhere throughout the document after the table has appeared.

3.2 Figures

If your thesis has a lot of figures, *R Markdown* might behave better for you than that other word processor. One perk is that it will automatically number the figures accordingly in each chapter. You'll also be able to create a label for each figure, add a caption, and then reference the figure in a way similar to what we saw with tables earlier. If you label your figures, you can move the figures around and *R Markdown* will automatically adjust the numbering for you. No need for you to remember! So that you don't have to get too far into LaTeX to do this, a couple **R** functions have been created for you to assist. You'll see their use below.

In the **R** chunk below, we will load in a picture stored as `reed.jpg` in our main directory. We then give it the caption of "Reed logo", the label of "reedlogo", and specify that this is a figure. Make note of the different **R** chunk options that are given in the R Markdown file (not shown in the knitted document).

```
include_graphics(path = "figure/reed.jpg")
```

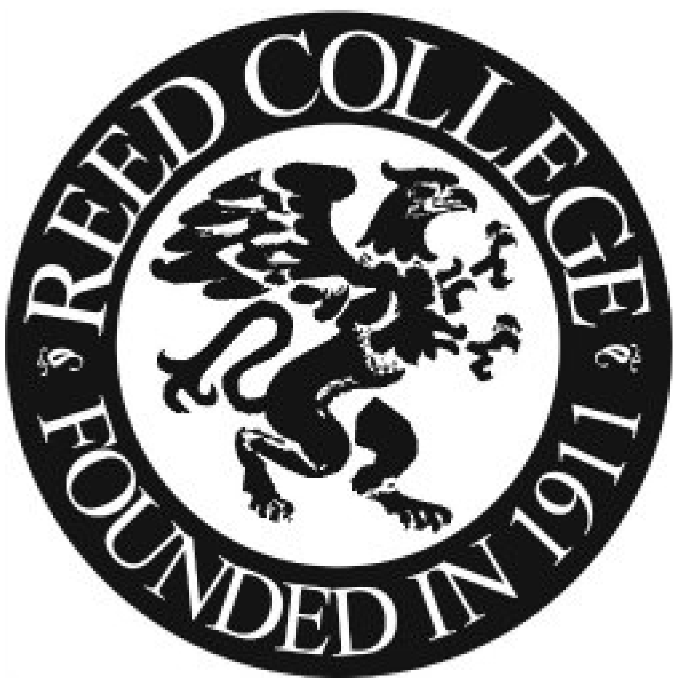

Figure 3.1: Reed logo

Here is a reference to the Reed logo: Figure 3.1. Note the use of the `fig:` code here. By naming the **R** chunk that contains the figure, we can then reference that figure later as done in the first sentence here. We can also specify the caption for the figure via the R chunk option `fig.cap`.

Below we will investigate how to save the output of an **R** plot and label it in a way similar to that done above. Recall the `flights` dataset from Chapter **??**. (Note that we've shown a different way to reference a section or chapter here.) We will next explore a bar graph with the mean flight departure delays by airline from Portland for 2014. Note also the use of the `scale` parameter which is discussed on the next page.

```
flights %>% group_by(carrier) %>%
  summarize(mean_dep_delay = mean(dep_delay)) %>%
  ggplot(aes(x = carrier, y = mean_dep_delay)) +
  geom_bar(position = "identity", stat = "identity", fill = "red")
```

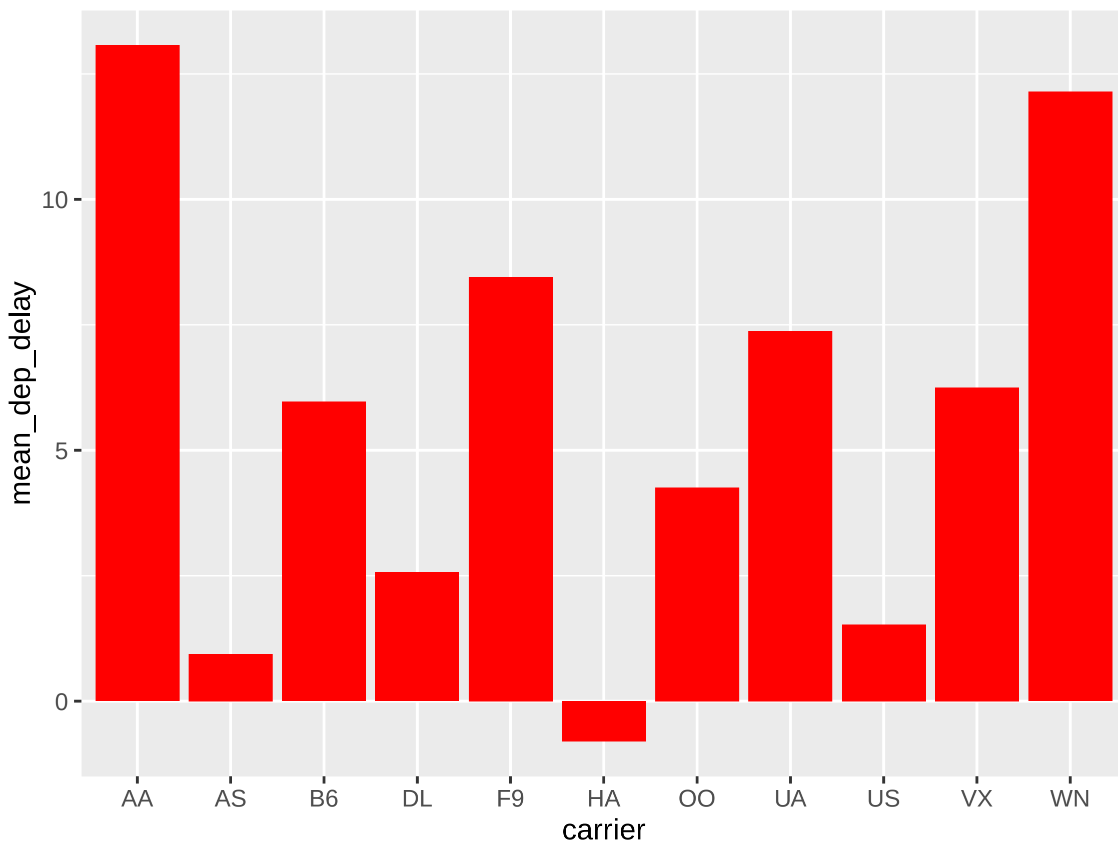

Figure 3.2: Mean Delays by Airline

Here is a reference to this image: Figure 3.2.

A table linking these carrier codes to airline names is available at `https://github.com/ismayc/pnwflights14/blob/master/data/airlines.csv`.

Next, we will explore the use of the `out.extra` chunk option, which can be used to shrink or expand an image loaded from a file by specifying `"scale= "`. Here we use the mathematical graph stored in the "subdivision.pdf" file.

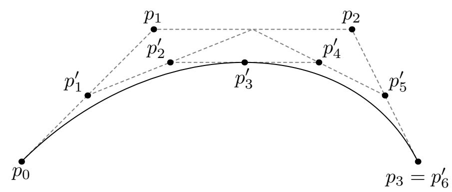

Figure 3.3: Subdiv. graph

Here is a reference to this image: Figure 3.3. Note that `echo=FALSE` is specified so that the **R** code is hidden in the document.

More Figure Stuff

Lastly, we will explore how to rotate and enlarge figures using the `out.extra` chunk option. (Currently this only works in the PDF version of the book.)

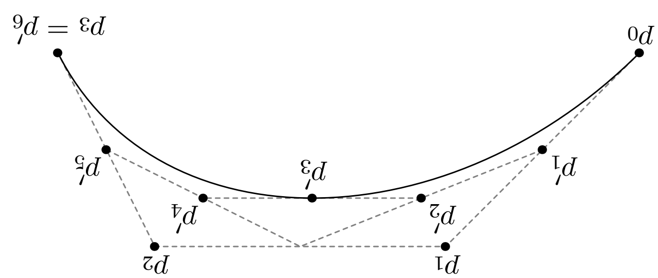

Figure 3.4: A Larger Figure, Flipped Upside Down

As another example, here is a reference: Figure 3.4.

3.3 Footnotes and Endnotes

You might want to footnote something. [1] The footnote will be in a smaller font and placed appropriately. Endnotes work in much the same way. More information can be found about both on the CUS site or feel free to reach out to `data@reed.edu`.

3.4 Bibliographies

Of course you will need to cite things, and you will probably accumulate an armful of sources. There are a variety of tools available for creating a bibliography database (stored with the .bib extension). In addition to BibTeX suggested below, you may want to consider using the free and easy-to-use tool called Zotero. The Reed librarians have created Zotero documentation at `http://libguides.reed.edu/`

[1] footnote text

`citation/zotero`. In addition, a tutorial is available from Middlebury College at `http://sites.middlebury.edu/zoteromiddlebury/`.

R Markdown uses *pandoc* (`http://pandoc.org/`) to build its bibliographies. One nice caveat of this is that you won't have to do a second compile to load in references as standard LaTeX requires. To cite references in your thesis (after creating your bibliography database), place the reference name inside square brackets and precede it by the "at" symbol. For example, here's a reference to a book about worrying: [@Molina1994]. This `Molina1994` entry appears in a file called `thesis.bib` in the `bib` folder. This bibliography database file was created by a program called BibTeX. You can call this file something else if you like (look at the YAML header in the main .Rmd file) and, by default, is to placed in the `bib` folder.

For more information about BibTeX and bibliographies, see our CUS site (`http://web.reed.edu/cis/help/latex/index.html`)[2]. There are three pages on this topic: *bibtex* (which talks about using BibTeX, at `http://web.reed.edu/cis/help/latex/bibtex.html`), *bibtexstyles* (about how to find and use the bibliography style that best suits your needs, at `http://web.reed.edu/cis/help/latex/bibtexstyles.html`) and *bibman* (which covers how to make and maintain a bibliography by hand, without BibTeX, at `http://web.reed.edu/cis/help/latex/bibman.html`). The last page will not be useful unless you have only a few sources.

If you look at the YAML header at the top of the main .Rmd file you can see that we can specify the style of the bibliography by referencing the appropriate csl file. You can download a variety of different style files at `https://www.zotero.org/styles`. Make sure to download the file into the csl folder.

Tips for Bibliographies

- Like with thesis formatting, the sooner you start compiling your bibliography for something as large as thesis, the better. Typing in source after source is mind-numbing enough; do you really want to do it for hours on end in late April? Think of it as procrastination.
- The cite key (a citation's label) needs to be unique from the other entries.
- When you have more than one author or editor, you need to separate each author's name by the word "and" e.g. `Author = {Noble, Sam and Youngberg, Jessica},`.
- Bibliographies made using BibTeX (whether manually or using a manager) accept LaTeX markup, so you can italicize and add symbols as necessary.
- To force capitalization in an article title or where all lowercase is generally used, bracket the capital letter in curly braces.
- You can add a Reed Thesis citation[3] option. The best way to do this is to use the phdthesis type of citation, and use the optional "type" field to enter "Reed thesis" or "Undergraduate thesis."

[2] @reedweb2007
[3] @noble2002

3.5 Anything else?

If you'd like to see examples of other things in this template, please contact the Data @ Reed team (email `data@reed.edu`) with your suggestions. We love to see people using *R Markdown* for their theses, and are happy to help.

Conclusion

If we don't want Conclusion to have a chapter number next to it, we can add the `{.unnumbered}` attribute. This has an unintended consequence of the sections being labeled as 3.6 for example though instead of 4.1. The LaTeX commands immediately following the Conclusion declaration get things back on track.

More info

And here's some other random info: the first paragraph after a chapter title or section head *shouldn't be* indented, because indents are to tell the reader that you're starting a new paragraph. Since that's obvious after a chapter or section title, proper typesetting doesn't add an indent there.

Appendix A

The Limitations of Modeling Pokémon Using Game Theory

In the main Rmd file

```
# This chunk ensures that the thesisdown package is
# installed and loaded. This thesisdown package includes
# the template files for the thesis.
if(!require(devtools))
  install.packages("devtools", repos = "http://cran.rstudio.com")
if(!require(thesisdown))
  devtools::install_github("ismayc/thesisdown")
library(thesisdown)
```

In Chapter 3:

```
# This chunk ensures that the thesisdown package is
# installed and loaded. This thesisdown package includes
# the template files for the thesis and also two functions
# used for labeling and referencing
if(!require(devtools))
  install.packages("devtools", repos = "http://cran.rstudio.com")
if(!require(dplyr))
    install.packages("dplyr", repos = "http://cran.rstudio.com")
if(!require(ggplot2))
    install.packages("ggplot2", repos = "http://cran.rstudio.com")
if(!require(ggplot2))
    install.packages("bookdown", repos = "http://cran.rstudio.com")
if(!require(thesisdown)){
  library(devtools)
  devtools::install_github("ismayc/thesisdown")
  }
library(thesisdown)
```

```r
flights <- read.csv("data/flights.csv")
```

References

- Ariely, D. (2009). Predictably irrational: The hidden forces that shape our decisions. New York, NY: Harper. Chapter 8: Keeping Doors Open (pp. 139-154).
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- Pokémon Showdown! battle simulator (n.d.). Retrieved October 31, 2016, from `http://pokemonshowdown.com/`
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- Schwalbe, U., & Walker, P. (2001). Zermelo and the Early History of Game Theory. Games and Economic Behavior, 34(1), 123-137. `doi:10.1006/game.2000.0794`
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