

UXG 1205

Introductory Probability and Statistics
Assignment 2

Pokémon and the Shiny Entei



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1 Introduction

1.1 History of Pokémon

Pokémon is a video game created in Japan by the video game company Nintendo in 1996. Multiple games have been released in the series, with the latest game being released in 2022, with many more games to be added to the series in the future. In Pokémon, the player takes on the role of a Pokémon trainer, whose main goal is to obtain pocket monsters, Pokémon in short, to train and battle. Each game generally has a different set of Pokémons, with around 200 catchable Pokémons per mainline title.

1.2 Gameplay

Pokémon gameplay revolves around 2 key concepts; exploration, Pokémon battles. Fundamentally, Pokémon's gameplay is tied to statistics and probability; the majority of game events are calculated with set probabilities.

1.2.1 Exploration

Pokémon cannot be what it is without one of the key gameplay features of exploration. Exploration in Pokémon can be defined as going to different areas or routes where different Pokémon are able to be encountered and caught. Many game events during exploration here are many game events during exploration that use the concepts of statistics and probability. One such event is Pokémon encounters, in which multiple probabilities are stacked on top of each other to give the players a sense of randomness to their encounters. In each encounter, probabilities are checked for not only whether an encounter is possible, but also what type of Pokémon, its gender, shiny status, ability and nature. More of this will be explained further in the report.

1.2.2 Pokémon Battles

Similarly, Pokémon cannot be what it is without the existence of Pokémon battles. Battling in Pokémon is very complex with each Pokémon having a moveset that is entirely up to the players to decide and figure out what is the most effective use to them. Furthermore, calculations of damage or effect chance are checked with data from both Pokémon in each turn, giving Pokémon a very dynamic gameplay loop for the players, with each battle being unique due to the different stats each Pokémon have but also with them having different abilities and types which interact differently to each single Pokémon.

1.3 Legendary Pokémon



Figure 1. Entei

Legendary Pokémons are extremely rare Pokémons with there only being one of each legendary in a game. Normally, legendary Pokémon can only be found at certain areas of the map in the game, with their encounter usually guaranteed as long as the player fulfills their prerequisite quests for them to appear in their respective areas. In contrast, roaming legendary Pokémon can be found across the map after the player fulfills their prerequisite quest. They don't stay in one area and move around the map.

1.3.1 Difference between Legendary Pokémon and Normal Pokémon

Legendary Pokémon are not only rare, but extremely powerful. Legendary Pokémon's base stats are larger than normal Pokémon. Legendary Pokémon's base stat total ranges from 600 to 720 while the strongest non legendary Pokémon of each generation has a maximum of 600 total base stat.

1.3.2 Entei

Entei is a roaming legendary Pokémon introduced in the second generation of Pokémon. Entei's prerequisite before being able to encounter it is meeting the three legendary dog Pokémon in the burned tower. The three legendary dog Pokémon are Suicune, Raikou and Entei. Entei and Raikou are roaming legendary Pokémons while Suicune has a set encounter. Raikou and Entei will be able to be found across the map, with their encounters requiring them to be in the same area or route as the player to have the opportunity for an encounter with one of them.

2 Probability in Pokémon

2.1 Probability in HeartGold and SoulSilver

This report will mainly explore the statistics and probability used in the main line games of Pokémon HeartGold and SoulSilver. As a mainline Pokémon game, HeartGold and SoulSilver align with the main game loop of Pokémon, exploration and Pokémon battles. This report will mainly focus on the exploration side, considering the depth that either part contains.

2.2 Encounter Rates

Encountering Pokémon in HeartGold and SoulSilver generally requires specific conditions of which there is one main condition, being in a game “tile” that an encounter is possible. Each time an encounter is possible, the game generates a random number between 0 to 2879. This number is then checked against the event’s hard coded encounter rate and if the generated number is less than the event’s encounter rate, an encounter is made. However, encounters can be prevented entirely by using a repel item and having a Pokémon on the first slot in the party being a higher level than any Pokémon that the game is generating from a possible encounter.

$$P(\text{Encounter}) = \frac{\text{Encounter Rate}}{2880}$$

Figure 2. Encounter Probability

2.2.1 Tile Encounters

Tile encounters in Pokémon are encounters where the game does a check on a data table whenever a player moves onto a new tile in the game that an encounter is possible. Such encounters are when the players step onto a tall grass tile, cave tiles, and surfing on a water tile with each having their own set of probability hard coded into the game. The most common encounters are encounters in tall grass with the majority of the routes containing a tall grass tile.

Tile	Encounter Rate
Tall Grass	320
Cave	160
Water	64

Table 1. Tile Encounter Rate

2.2.2 Action Encounter

Action encounters in Pokémon are encounters in which the player must do an action other than walking to generate an encounter. Such events are when the player breaks a rock with the move rock smash and using the Pokémon move Sweet Scent in a tile that a tile encounter is possible. As seen in [Table 2], Sweet Scent has an encounter rate of 2880, which if substituted into [Figure 2], Sweet Scent has a 100% guaranteed rate of triggering an encounter event as long as the player is on a tile that an encounter is possible to happen.

Tile	Encounter Rate
Rock Smash	320
Sweet Scent	2880

Table 2. Action Encounter Rate

2.2.3 Pokémon Generated

Once an encounter is made, a Pokémon is generated. Each route has a table set of Pokémon that the game pulls from, with certain characteristics also randomised such as Individual Values (IVs) which are changes to the Pokémon stats, to their gender and the Pokémon's ability. Furthermore, the Pokémon generated could be different based on the player's in game time.














Pokémon	Games	Location	Levels	Rate		
						
 Pidgey	HG SS	 Grass	2-4	55%	55%	0%
 Rattata	HG SS	 Grass	4	5%	5%	0%
 Rattata	HG SS	 Grass	2, 4	0%	0%	15%
 Sentret	HG SS	 Grass	2-3	40%	40%	0%
 Hoothoot	HG SS	 Grass	2-4	0%	0%	85%

Figure 3. Example Pokémon Generation Table of Route 29

2.3 Roaming Legendary Encounters

2.3.1 Roaming Legendary Route Movement

Roaming Legendaries in HeartGold and SoulSilver consists of two Pokémon, Entei and Raikou. An encounter with a roaming legendary has one major prerequisite, the Pokémon must be in the same area or route as the player.



Figure 4. Game Map with Roaming Legendary indicator

As seen in [Figure 4], roaming legendaries show up on the game map, indicating with an icon which legendary is currently at a specific route or area. The roaming legendary moves in a certain way whenever the player moves around the map. When the player moves from one area or route to another through an outdoor route; the player cannot go through indoor routes such as caves or tunnels, the roaming legendary moves from their current area or route to an adjacent one. This can be expressed in an equation.

$$P(Roam) = \frac{1}{N}$$

N = Amount of Adjacent Routes / Areas to current Route

Figure 5A. Probability that the Roaming legendary from 2 routes away roams into the player's next route that they go into

However, the game introduces another mechanic to the way the roaming legends roam. This is where the roaming legendary has a chance to go to a random route anywhere on the map. The probability of this happening can be expressed in an equation.

$$P(\text{RoamEverywhere}) = \frac{1}{8}N$$

N = Amount of Adjacent Routes / Areas to current Route

Figure 5B. Probability that the Roaming legendary goes to a random spot in the Map

This means that the original equation [Figure 5A] of the Pokémon roaming to an adjacent route that is the player's route that they are heading into must be adjusted with this change. Furthermore, we can create a new equation to show the probability that the random route the roaming legendary goes to from [Figure 5B] be the one that the player is heading into.

$$P(\text{Roam}) = [(1 - \frac{1}{8}N) \times \frac{1}{N}]$$

Figure 5C. Adjusted probability of [Figure 5A]

$$P(\text{RandomRoamToPlayer}) = (\frac{1}{8}N \times \frac{1}{P})$$

P = All the possible Routes / Areas in the map the Roaming Legendary can traverse into

Figure 5D. Probability that the [Figure 5B] goes into the same route the player is heading into

2.3.2 Roaming Legendary Encounter

Encountering a Roaming Legendary in HeartGold and SoulSilver is very similar to encountering a normal Pokémon. The rate of generating an encounter is the same as a normal Pokémon, with it using the same equation [Figure 2] with the encounter being tied to encounters with normal Pokémon. However, in contrast to [Figure 3], the probability of generating the roaming legendary Pokémon once an encounter has been triggered is different, with the equation [Figure 6] representing the probability that the generated Pokémon is the roaming legendary

and the other being the probability that the generated Pokémon is pulled from a table similar to that of [\[Figure 3\]](#).

$$P(\text{GeneratingRoamingLegendary}) = 0.25$$

Figure 6. Probability of generating a Roaming Legendary

2.4 Other Encounter Related Probabilities

2.4.1 Shiny Pokémon



Figure 7. Difference between a normal Pokémon with a Shiny Pokémon

Shiny Pokémon are Pokémon who have a different color palette from the original Pokémon they are based off. Shiny Pokémon have no inherent difference in stats or possible abilities and the changes are purely cosmetic. However even with no advantage in having them, they are very popular in the Pokémon community not only due to the difference in their colours but also due to their rarity, with the probability of generating a Shiny Pokémon in an encounter is as follows.

$$P(\text{Shiny}) = \frac{1}{8192}$$

Figure 8. Probability of a Shiny Pokémon

2.4.2 Pokérus



Figure 9. Pokémon with Pokérus

In contrast to Shiny Pokémon, Pokémon with Pokérus have differences that are entirely gameplay based with no cosmetic difference to normal Pokémon other than an indicator in the game user interface that shows that the Pokémon has this condition. Pokérus is inherently a virus, in which a generated Pokémon may have the probability to have. Being a virus, Pokémon with Pokérus are able to infect other Pokémon in the player's party. Pokémon with Pokérus gain double the Effort Values(EVs) when battling, with EVs allowing the Pokémon to gain more stats than normal through battling, giving Pokémon with Pokérus an inherent advantage. However, to even be able to get Pokérus is one of the rarest events in Pokémon, with [\[Figure 10\]](#) as the equation of it being able to occur.

$$P(\text{Pokérus}) = \frac{3}{65536}$$

Figure 10. Probability of finding a Pokémon with Pokérus

2.5 Reasoning for Probability

Pokémon has always been a game that utilizes probabilities in its calculations, be it in encounters or even in Pokémon battles. This can be mainly attributed to the age of the game [1.1], in which the easiest way to showcase the multitudes of different Pokémon to the user is through cycling through them on encounters. Random chances of finding different Pokémon in each encounter enhances player engagement through the suspense and anticipation of the possibility of finding a new Pokémon each time. Furthermore, the rush of dopamine is exacerbated whenever the player gets a Pokémon they have been looking for hours due to their perceived value due to their rarity. In fact, Pokémon has been going into a different direction in their recent games, due to the advancement in technology, with more up to date games showing the Pokémon in the world itself [Figure 11], with the probability of them appearing still the same as previously mentioned, but the caveat is that there are no longer any encounters in the game with the Pokémon just being generated as the players travel the game world and battles are triggered through contact with the player and the wild Pokémon. It can be argued that the new direction Nintendo is going with is good as it allows more player agency, however the opposite can be said in that it takes away the experience of danger that is quite common in older Pokémon games in which Pokémon Battles are forced to the player with each encounter, making exploration more intense and increases player engagement in the process.



Figure 11. Pokémon generated in the game world instead of encounters

3 Interesting use of Probability

3.1 The Rarest Possible Entei

With all this data, we can try to calculate the probability of finding one of the rarest Entei; **one with Pokérus and is Shiny, just within the first area that the player moves into and with the first encounter that they make on the first tile encounter possible.** For this, the move Sweet Scent will not be used due to it being able to trigger instant encounters [\[Figure 2\]](#)[\[Table 2\]](#). This can be divided into the encounter itself and the Entei generated.



Figure 12. Entei with 2 other Legendary Pokémon in the Burned Tower

3.1.1 Encountering Entei

From the events of the game, the earliest the player can try to encounter Entei is directly after seeing it in the Burned tower. The Burned Tower is located in Ecruteak City [\[Figure 13\]](#), which is a city with three connections, one to the East, one to the West and one to the South.

Considering roaming Legendary Pokémon movement [\[2.3.1\]](#), the connections to the east and west of Ecruteak City are through tunnels, the first route the player can go to in which the player can trigger Entei to move is through the south, Route 37.

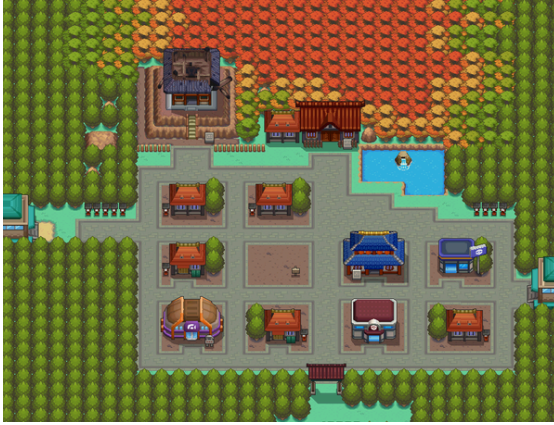


Figure 13. Ecruteak City



Figure 14. Route 37

From the equations in [Figure 5C][Figure 5D], we can get the lower probability of either equation as the probability that Entei moves into Route 37 when the player travels from Ecruteak City into it. For this equation[Figure 5C], it can be assumed that Entei has been put in the world map to be in Route 36, the only route adjacent to Route 37 in which Entei can be put into, due to Route 37 only having two connections, the other being Ecruteak City where Entei cannot be encountered. Due to this, the probability of Entei being generated in Route 36 must be taken into account, with the amount of generatable routes being 17. As such, the probability of Entei generating in Route 36 and moving into Route 37 is 0.0074.

$$P(36) = (((1 - \frac{1}{8}N) \times \frac{1}{N}) \times \frac{1}{P}) = (((1 - \frac{1}{8}4) \times \frac{1}{4}) \times \frac{1}{17}) = \frac{1}{136} = 0.0074$$

N = Number of adjacent moveable routes

P = Number of generatable routes

Figure 15A. Probability Entei moves into Route 37 from Route 36

In contrast using the other equation [Figure 5D], the probability of Entei generating into a random route and moving into Route 37 without moving into an adjacent route will be as follows [Figure 15B]. As the random routes could have a varying number of adjacent moveable routes, the range of adjacent moveable routes is between 1 to 4, the probability could be adjusted with the varying value of N .

$$P(\text{RandomRoamToPlayer}) = \left(\frac{1}{8}N \times \frac{1}{P}\right) = \left(\frac{1}{8}N \times \frac{1}{17}\right)$$

N = Number of adjacent moveable routes

P = Number of generatable routes

Figure 15B. Probability Entei moves into Route 37 from a random route

N	P(RandomRoamToPlayer)
1	1/136
2	2/136
3	3/136
4	4/136

Table 3. Range of Probabilities that Entei moves into Route 37 from a random route

From the values of [Figure 15A] and [Table 3], it can be observed that the lowest value is $\frac{1}{136}$, which would be the value which will be used for our final calculation. With this, the values of [Figure 2][Table 2][Figure 6] would be substituted to get the probability that an encounter is made on the first tall grass tile and the encounter being Entei.

$$P(EE) = P(\text{TallGrass}) \times P(\text{GeneratingRoamingLegendary}) = \frac{320}{2880} \times 0.25 = \frac{1}{36}$$

Figure 16. Probability Entei encounter on first tall grass tile

3.1.2 Generating Special Entei

To generate a special Entei that is Shiny and with Pokérus, the equations of [Figure 8][Figure 10] could be combined using the multiplication rule.

$$P(SPE) = P(\text{Shiny}) \times P(\text{Pokérus}) = \frac{1}{8192} \times \frac{3}{65536} = \frac{3}{53706752} = 0.0000000558$$

Figure 17. Probability of a Shiny Entei with Pokérus

3.2 The Final Numbers

As such, using the figures from [\[3.1\]](#), the probability of finding an Entei **with Pokérus and is Shiny, just within the first area that the player moves into and with the first encounter that they make on the first tile encounter possible** would be as follows.

$$P(Final) = P(36) \times P(EF) \times P(SPE) = \frac{1}{136} \times \frac{1}{36} \times \frac{3}{53706752} = \frac{1}{87649419264}$$

Figure 18. Final Probability

With everything accounted for, the probability of getting such event is a mind boggling 1 in 87649419264 chance!

4 Conclusion

As demonstrated by this report, the world of Pokémon is dictated by the rules of probability and as such with everything randomized, each player's experience is entirely different compared to another player. Calculating every single possibility in the game leads to a rabbit hole that shows exactly how much each player has a varied experience compared to their peers. In fact, this report only covered one aspect of Pokémon and it is not even to the full extent, with fishing and Pokémon stats not explained. This can explain the massive fanbase and the support Pokémon has received from its players since it was first released in 1996 until up to the present day. As such, with its gameplay intertwined with statistics and probability, there is no doubt that Pokémon would be successful in the generations to come.

References

Bulbapedia contributors. (n.d.). List of routes: Johto. Bulbapedia.

https://bulbapedia.bulbagarden.net/wiki/List_of_routes#Johto

Bulbapedia contributors. (n.d.). Entei (Pokémon). Bulbapedia.

[https://bulbapedia.bulbagarden.net/wiki/Entei_\(Pok%C3%A9mon\)](https://bulbapedia.bulbagarden.net/wiki/Entei_(Pok%C3%A9mon))

Bulbapedia contributors. (n.d.). List of in-game event Pokémon in Pokémon HeartGold and SoulSilver: Entei. Bulbapedia.

https://bulbapedia.bulbagarden.net/wiki/List_of_in-game_event_Pok%C3%A9mon_in_Pok%C3%A9mon_HeartGold_and_SoulSilver#Entei

Bulbapedia contributors. (n.d.). Wild Pokémon. Bulbapedia.

https://bulbapedia.bulbagarden.net/wiki/Wild_Pok%C3%A9mon

Bulbapedia contributors. (n.d.). Tall grass. Bulbapedia.

https://bulbapedia.bulbagarden.net/wiki/Tall_grass

Bulbapedia contributors. (n.d.). Pokérus. Bulbapedia.

<https://bulbapedia.bulbagarden.net/wiki/Pok%C3%A9rus>

u/[xeldablade025]. (2024, October 25). Are random encounters outdated? [Online forum post]. Reddit.

https://www.reddit.com/r/JRPG/comments/17fx0bp/are_random_encounters_outdated/

pret. (n.d.). wild_encounters.json. In pokeemerald (Version master) [Repository]. GitHub.

https://github.com/pret/pokeemerald/blob/master/src/data/wild_encounters.json

pret. (n.d.). wild_encounter.c. In pokeemerald repository. GitHub.

https://github.com/pret/pokeemerald/blob/master/src/wild_encounter.c

Fobby.net contributors. (n.d.). Pokémon statistics [PDF]. Fobby.net.

https://ssl-forum-files.fobby.net/forum_attachments/0029/3387/Pokémon_Statistics_nice.pdf

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