Cooperation as a Strategy

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INTRODUCTION

Bernd Heinrich, professor emeritus at the University of Vermont, is best known for his studies on insect physiology and behavior. While studying the behavior of bumblebees, he stumbled across a rather interesting conundrum. ravens, normally known to be solitary animals, were sharing valuable food amongst themselves. It intrigued him such that he performed studies on cooperative raven behavior for a number of years in the woods of Maine. He wrote a book, *Ravens in Winter*, which describes what he refers to as recruiting behavior.

> In some of the same fields and woods where I had made the observations on bumblebees, I had often noticed a pair of ravens. I now saw the birds, which had always seemed to me solitary animals, doing something solitary animals are not 'supposed' to do: They were sharing valuable food- those who had, it seemed, were given to those who needed. It was the most left-wing behavior I had ever heard of in a natural system. Furthermore, it did not make sense. (As a biologist interested in how things work, I always look for some evolutionary, self-serving reason for why animals do things, although this is totally apart from the animals' motives, and even more removed from what 'ought' to be in terms of human behavior.) This time my mind failed to provide a clearly selfish, evolutionary cause for the apparent sharing, and that failure gave me an instant adrenaline rush. I felt that I might not only learn something about ravens, but also something of larger theoretical value. (12)

As one can see, this instance of raven behavior is rather curious. Here Heinrich explains that from the standpoint of a behavioral biologist, these behaviors at first seem illogical. On the surface there seems to be no clear advantage for this individualistic animal's cooperative behavior, but through this essay we will explore why this might not be the case. Although there are many instances where being "selfish" grants the highest chance of success to an individual, there are indeed many scenarios where the opposite is true. This essay will evaluate evolutionarily stable strategies and apply game theory to the behavior of ravens in order to understand and explore the theoretical benefits of cooperation.

EVOLUTIONARILY STABLE STRATEGIES

An evolutionarily stable strategy is a behavior, or collection of behaviors, that is considered "impenetrable" by other "mutant" strategies. This means that a new strategy will not replace it, since the more stable strategy leads to higher success and survival for the individual in comparison to outlying or competing strategies. Because those that follow the evolutionarily stable strategy are more likely to be successful, natural selection within their community will weed out the other non-sustainable strategies over time. It is of note that Heinrich also describes the stable strategy as the "rational (mathematical)" one- meaning the strategy that sets up the individual with the highest percent chance of success.

The Selfish Herd Hypothesis is a rather simple theory. First pushed forward by British Zoologist W.D. Hamilton at the University of Michigan in 1971, it attempts to explain why an evolutionarily stable strategy for some animals is to gather in crowds (Heimrich, 76). If there is some sort of threat, for example, a predator, the risk is diminished for an individual if they are grouped up with many others of their species.

Therefore, it is advantageous for the individual to be in a large group as a form of protection. In other words, an individual in a herd is mathematically less likely to be picked off by a predator. However, as the raven is a large bird with few actual predators, ravens most likely do not gather in order to deter such threats.

The Hawk-Dove theory, on the other hand, is more complex. It is a theory relating to evolutionarily stable strategies first coined by John Maynard Smith, a behavioral ecologist at the University of Sussex. In this famous analogy (or model of conflict) an animal can either be a hawk (which is defined as one who always escalates until it either wins or is seriously injured) or a dove (one who never escalates and backs down if the opponent escalates). The participants fighting over a resource, such as food, never know beforehand which strategy their opponent will employ, as both hawks and doves essentially look the same (Hiemrich 106,107). It is better for the individual to be a hawk when there are lots of doves, as there is little danger of retaliation. Essentially, the hawk simply escalates until the dove backs down and takes the prize. However, when the chances of confronting a hawk are high, it is advantageous to be a dove as to avoid injury. This is because if two hawks confront each other, as they tend to escalate confrontations, there is a high chance of injury. As escalation can also lead to a waste of resources by both parties, oftentimes the risk is higher than the reward.

Since the relative success of either strategy is dependent upon the frequency of encountering the other, neither strategy can exist long by itself. When doves are plentiful, a hawk will thrive. When hawks are plentiful, doves are more successful. Therefore, in the long run, the real evolutionarily stable strategy, or “rational” darwinian strategy for a population, is not actually either hawk or dove, but a balance between the two where costs (injury, death and waste of resources) and benefits (rewards for winning a contest) compromise to maximize reproduction.

In some cases, the Hawk-Dove theory does not directly assist in the analysis of raven behavior as it presupposes that any two individuals only encounter each other once. If one has encountered an individual before, and knows them to be a dove, one can change their strategy to that of a hawk in order to acquire the resource, and vice versa. This can be compared to a game of rock-paper-scissors. If you know your opponent was going to throw out rock, you would naturally switch to paper in order to win.

As ravens are territorial and not migratory, they will encounter other individual ravens multiple times. it is not a point of contention that these birds have the ability to recognize each other individually as well as have long memories. This meets the prerequisites for the possibility of reciprocation as noted by Heinrich (107), because a raven may receive a favor in return for granting one. This is an important requirement for ongoing cooperation, as discussed further herein.

PRISONER’S DILEMMA

Another particularly important concept for exploring ideas of cooperation from a strategic analysis perspective is the Prisoner's Dilemma. As one of the most well-known concepts in modern game theory, it is basically a scenario in which two parties who are separated and unable to converse have to choose whether or not to cooperate with the other. The highest reward for both parties occurs when they choose to cooperate, but each of them have incentive to defect. Essentially, each party must consider how much they trust the other to choose the mutually beneficial option, or they could potentially be selfish and incriminate the other party- which would grant them a greater individual gain. However, if both of them choose the selfish choice, neither of them win. Where the Prisoner's Dilemma becomes especially interesting is when the two parties meet recurrently, as they also have to think of how their actions will affect their relationship in future confrontations. In many instances the ravens competition over carrion can be analogous to the Prisoner's Dilemma. When two ravens encounter carrion, they are given a choice: either cooperate with the other or compete over the ability to feed. This also goes hand in hand with the Hawk-Dove theory- the raven can exhibit hawk behavior and escalate in order to feed on more carrion by themselves, or try to cooperate (dove), backing off if the other tries to escalate. As mentioned earlier, each behavior is only advantageous depending on what the other party picks. However, how can one accurately and reliably predict what behavior the other party will choose, especially if they are trying to choose the best strategy against you as well?

<u>EVOLUTION OF COOPERATION ROBERT AXELROD</u>

The Prisoner's Dilemma is explored in depth in *The Evolution of Cooperation* by Robert Axelrod. Simply put, the book is an extension of a prominent paper of the same name. It explores how cooperative behaviors could emerge and exist as a strategy from a game theory perspective. Axelrod created a computer simulation of the prisoner's dilemma, assigning a point system that awarded different values based on the options each party chose. The greatest point yield was given to parties that defect while their opponent tries to cooperate, but a very low point yield was given to parties who both defected at once as well as a party that tried to cooperate when its opponent defected. A moderately high point yield was given to parties who cooperated with each other. Furthermore, Axelrod ran the same two parties against each other fifty times, and produced a round robin style tournament where each party got a chance to interact with one another. Each party had its own strategy, a set of rules it followed on how to act based on the former interactions with the opposing party. The most prominent strategies included Tit for Tat, All D, and Tester.

Tit for Tat is rather simple: try cooperating in the first interaction, and then from there you mirror your opponents last action. If they choose to cooperate, then continue to cooperate. If they choose to defect, then you defect in turn. If they defect and then try cooperating again, you do the same. What is rather interesting is that with all the simulations, Tit for Tat consistently scored the highest when placed against so many different, sometimes complex, strategies. This is likely due to the fact that although it is incredibly simple, the Tit for Tat strategy adapts immediately to the opponent's behavior. Furthermore, as Tit for Tat is unforgiving to those that defect against it, it discourages manipulative behavior by the other party.

All D is even simpler: never cooperate and always defect to try to get the highest individual yield. Obviously when placed against other aggressive strategies the yield is very low; however it is just as low as the more cooperative strategies against defecting strategies. And when All D is up against “softer” cooperative strategies it gets away with a very high point yield. Also, All D is forever lowering the point values of the other parties in contention as it never cooperates. So, when you look at it from this perspective, it is no surprise that All D actually is a consistent high finisher.

Tester is a rather interesting strategy. It starts out essentially the same as tit for tat, however after a few rounds of cooperation the tester will then pull a fast one on the other and defect for a few extra points. This strategy strikes a balance between the Tit for Tat and All D strategies, giving a slight advantage over the softer strategies. However, against some of the less forgiving strategies such as Tit for Two Tats (where you defect twice for every time the other party defects), the Tester loses out on points.

What is perhaps most interesting about all these strategies and evolutionary behaviors is how dependent they are upon the opposing strategy. As I highlighted earlier in my Hawk-Dove theory section, the Dove is more successful when there are lots of hawks in the mix, whereas the Hawk is more successful when there are lots of Doves.

Even very stable, strong strategies such as Tit for Tat can easily be bested if the opponent knows that the Tit for Tat strategy is being used. It is important to note that although the Prisoner's dilemma can be used to understand competition over resources, it is almost always a generalization, and the real environment will be significantly more complex.

However, this sort of logical behavioral analysis can be applied to any sort of lifeform that makes behavioral choices in response to its environment. Axelrod points out "there is a broad range of biological reality that is encompassed by this game-theoretic approach."(93) In fact, an organism does not even need a brain to employ a strategy. Even bacteria have a basic ability to play games as they are highly responsive to certain aspects of their environment, especially their chemical environment. This suggests that they can respond differently to what other organisms around them are doing, that these conditional strategies can be inherited through reproduction, and that the behavior of a bacterium can affect the fitness of other organisms. However while a bacterium's strategies can consist of responses to recent environmental changes as well as cumulative averages over time, bacteria cannot remember or interpret a complex past sequence of changes, and cannot distinguish the origins of changes. For example, some bacteria produce bacteriocins, their own antibiotics that are harmless to themselves but harmful to other strains of bacteria. The bacteria could be wired to produce bacteriocin when it perceives hostile products in its own environment, however it can not aim the toxin towards any particular offender.

Obviously as humans and more intelligent creatures such as ravens can retain memory and learn behaviors, the options and strategies of the individual become increasingly rich and complex compared to say, an amoeba. But perhaps the biggest game-changer (pun intended) is the ability to recognize and remember other individuals, as one's strategy can then change based on past experiences with an individual. Complex creatures like ravens can distinguish between foreign objects in their environment as well as associate events with them.

HUMAN LIFE AS AN EXAMPLE

To better understand what an evolutionarily stable strategy is, I believe it is a good idea to take a look at human life, something we directly relate to. Theoretically, there are many evolutionarily stable strategies within our own society. For example, one could say that being respectful when you meet a new stranger is such an example in our western culture. If someone is rude to new individuals that they meet, they will have trouble making connections both in a business setting as well as in their personal life. Oftentimes, this would be significantly disadvantageous to them as an individual compared to being respectful and earning the favor of those they meet. The person who has many people willing to do them favors and set them up for success has a large advantage compared to someone that is generally disliked throughout their community. But the hawk dove theory brings up an interesting point. Let’s say that being respectful is a dove strategy, whereas being disrespectful is a hawk strategy. There are perhaps several boons to being disrespectful to some of those you meet- perhaps if they are very polite and kind one could walk all over them and take things from them that one would normally be afraid to do out of respect. Or maybe you would come off as more self-assured and powerful, which could be a boon in its own way. Perhaps simply not wasting time and energy with pleasantries turns out to be especially advantageous for an individual. Regardless, to be evolutionarily stable, the strategy simply has to set up the individual with overall success. In fact, both strategies could be considered evolutionarily stable. There is certainly a reason why the jerk elite archetype exists. But the community will naturally form a balance between these two strategies. If everyone was rude and tried to command others this strategy would essentially be rendered ineffective as It would just lead to constant egotistical conflict between individuals, and individuals who act respectfully to one another would have a significant advantage in this hypothetical society.

According to the hawk dove theory, in this hypothetical scenario doves (politeness) would have an advantage as they could work together and avoid unnecessary conflict while all the hawks continue to fight over their own resources. But in a world where the majority is passive and polite, the hawk would be advantageous, as they could simply take resources for themselves with little to no pushback. Eventually natural selection would strike a balance between the two types within society based on the community's environment- as the prosperity of each strategy is dependent upon the strategies other individuals are using. If there are more hawks around dove numbers will slowly increase as it is a more successful strategy. Natural selection will be more likely to pick off individuals using the weaker strategy- in this case the hawks, and the ratio of strategies will reach something of an equilibrium. Like predator-prey populations, the success of both behaviors is directly connected to the success of the other, and will cyclically fluctuate back and forth.

Picture a competitive hard-working businessperson. They have started a new company that is growing exponentially, and have a hard decision to make: they can outsource labor to a foreign country in order to create a much higher net profit on their product, or they can continue to have labor done within their region at a higher cost. Assuming there are no labor laws against this, or repercussions from their own community, outsourcing labor is the most advantageous choice for their company, and in turn the evolutionarily stable strategy for them, as their own individual success is tied to the success of the company. Oftentimes, human morals affect these strategies insofar as how other individuals will react. If a society has morals that go strongly against the actions of an individual, the punishment for this individual will oftentimes be heavier than the benefits the strategy gives, thus rendering it non-sustainable.

For example, robbing banks is not an evolutionarily stable strategy because the lawful community will punish the individual, and the risk to the individual outweighs the advantages. Even if an individual or a small group of individuals are very successful and do not get caught, acquiring lots of advantageous resources, in this case money- they would be outliers as most bank robbers would get injured or caught. If bank robbing became more and more prevalent as a strategy, the lawful community would most likely react by heightening the levels of security around banks, creating an unreasonably high risk-reward ratio for these individuals. Therefore bank robbing will most likely never be an evolutionarily stable strategy.

But obviously current evolutionarily stable strategies can (and will most likely) be replaced as the environment changes. Re-imagine the booming company scenario, but this time let’s say that the economy of their region is associated strongly with their company's success- and that the company is employing a large amount of local workers. Furthermore the region the company would outsource labor to is in competition with the original home region. It’s very likely that the home region would perhaps lower minimum wages to compete, or grant benefits/privileges to the company- perhaps maybe give a general tax break if they agree to have their labor stay in the home region. In this new scenario, the business community in the region will most likely develop a new evolutionarily stable strategy, that of keeping labor local. This would replace the old strategy of outsourcing labor to another region. One might say, “Well, by definition, wouldn’t the strategy not have been an evolutionarily stable one to begin with if it was penetrated by this new strategy?” However, as the situation and circumstances surrounding the community changed, what was the best strategy naturally changed as well. These strategies are evolutionarily stable since they are impenetrable as long as the environment stays the same.

RAVENS BACKGROUND

Ravens are a member of the corvidae family, which consists of birds such as ravens, crows, jays, and magpies. Corvids are medium to large-sized perching birds with rounded wings and tails. The North American members of this family typically have wingspans that range from twenty nine inches to four feet five inches, and all have strong bills and feet. Ravens are the largest members of the corvidae family.

Corvids are generally bold, noisy, and gregarious, and almost all terrestrial North American habitats, including some of the harshest areas, such as deserts and the high Arctic are home to at least one species. Members of this genus, especially crows and ravens, are supposedly among the most intelligent of all birds. In fact, in some psychological tests crows have performed on par with monkeys. Furthermore, ravens and magpies have a nonverbal ability to "count" up to seven- meaning they recognize and can distinguish groups of different sizes up to seven. They can fulfill this task about as well as people who make the assessment without using words to count.

Corvids are also generally very social birds. When in groups, especially large groups, many corvids, such as jays and crows, will protect one another. When in these groups, some birds will opt out of foraging in order to act as sentinels- sitting conspicuously upon exposed perches. Unlike other birds such as flycatchers that forage from such perches, these sentinels will rarely drop down or sally for food, instead keeping a careful watch and sounding an alarm call when it spots a predator. When it gives this alarm call, the other group members will hide or fly away, or mob and attack the predator (depending on the call given). This behavior clearly demonstrates a corvids propensity, or at least ability, to cooperate. The groundwork for our study is clear here: these corvids are not only intelligent, they have clear intricate social behaviors.

The question remains: why did these ravens share valuable food with one another when it does not seem to benefit them? After many months of observation, Heinrich noticed a pattern. The birds that shared food were all adolescent.

Ravens are territorial, with a dominant mating couple holding said territories. But where does that leave the rest of the birds that are too old for the nest but too young to lay claim to a territory? Adolescent ravens actually form large roosts together, especially during harsher times such as winter. These roosts can make quite a spectacular site, with hundreds of rather large birds occupying a single tree. The young ravens have constant social interaction at the roost, practice courting behavior (but do not form pairs yet), and organize hierarchies. They can be rather gregarious with many loud disputes that even get rather physical. However, there seem to be certain rules to these fights- even in the most stressful situations you will never see another raven try to peck at another's eye. As the eye is the ravens most important tool for survival, disabling a ravens eyesight is essentially a death sentence.

This distinction is important to understanding the interactions between these creatures. If attacking a fellow roost-mate's eyes was fair game for these ravens, every dispute would become significantly more dangerous for all involved birds. Therefore, if eye-fighting behavior arose as a mutant strategy in a small group of ravens it would be weeded out by natural selection. For example, even if it gave certain eye-fighting birds an advantage over the rest, and these eye-fighting ravens spread the mutant behavior through reproduction and contact with other ravens, the eye-fighting birds expose themselves as well as their fellow ravens to significantly more danger.

As mentioned briefly earlier, ravens have been proven to remember and be able to distinguish individuals among themselves. No doubt you may have heard the stories of ravens and crows not only remembering human individuals but also having negative or positive associations with them. These folk-tales are actually very true, and supported by a rather sizable amount of research (Gannon, Live Science). It goes without saying that this research proves that ravens have different associations with individuals of their own species as well.

RAVEN COOPERATIVE BEHAVIOR

One of the many things that puzzled Heinrich during his studies was that there seemed to be many inconsistencies with when and how the ravens displayed cooperative sharing behavior. There were many instances where a raven would spot carrion and partake immediately as an individual. There were other times where a raven would spot the carrion and actually pretend that they did not see it, or times when a raven would just hover around the carrion for long periods of time, just watching. This is where Heinrich began to truly appreciate how fascinating the raven behavior really was. The raven behavior was a complex, strategic battle over each individual's success with access to the carrion.

As I mentioned earlier, the territory is controlled by a dominant pair. As the dominant pair are stronger and older than all the young vagrants in their territory, they essentially get first dibs on carrion, and will often bully the other ravens off of a feeding spot. However, if a young raven spots it first and is able to eat before the dominant pair realize, the carrion is fair game. But the young raven can also do something else to bolster his chance of success and survival. By leading other adolescent ravens to the carrion, the young raven can set up a system where the other ravens that it helped might one day return the favor, as well as secure the carrion from the prying talons of the dominant pair (through a simple strength in numbers). This ensures that it gets to continue eating in times where it’s usual feeding methods are unsuccessful. But the success of this strategy is entirely dependent on the reciprocity of the other ravens. Not only are the other young ravens not guaranteed to return the favor, the organizing raven must strike a balance of sorts to maximize carrion accessibility. For, if the young raven recruits too many other ravens, the recruiting raven will not be able to partake of nearly as much sustenance as it otherwise could. This is where the intrigue begins.

The young raven has been observed to pretend not to see carrion when it actually does, only to return very cautiously a little later. This is likely due to fears of other ravens noticing its reaction- indicating them to the presence of the carrion.

In a similar vein, if the young raven is looking to recruit from the roost, it has to be secretive in order to not alert too many other ravens. As the raven does not really have any natural predators, and does not really have competition on carrion sites from most other animals, it seems safe to say that a raven's main competition is other ravens. In fact, ravens will almost always ignore crows on sites, but fight other ravens for the food. Perhaps this is because the ravens know that they can push the crows off the site if they wish, so they do not feel the need to compete with them (as there is no real competition).

COOPERATION IN GENERAL

Ultimately, it is not actually a matter of selflessness or selfishness. It is simply the strategy that sets up an individual with the highest chance of success that persists. Cooperation across a community can benefit the individuals greatly, but there are certainly scenarios where a more hawk-like approach sets the individual up with more success. The dominant pair never showed recruiting behavior, as taking the carrion for themselves is simply the better strategy for them. As long as the young ravens do not use recruiting behavior, the dominant pair can bully any other ravens off of the site and access food. But the smaller young ravens do not have such a luxury. Because cooperation can essentially be an investment of resources, there are actually times where even though the short-term benefits of cooperation are significantly lower than not cooperating, the cumulative benefits (including short and long term) of cooperation are significantly higher than any alternative. As seen with the young ravens, not only did the recruiting behavior ensure that the dominant pair could not take away precious carrion access, it also opened up the young ravens to other opportunities where their fellow adolescents would recruit them for other sites. The key to this is reciprocation, for if the other young ravens do not recruit them back at another opportunity, the recruiting raven loses out in the end.

The main requirement of reciprocation is the ability to recognize and associate events with other individuals, and in many instances cooperation requires reciprocation in order to function properly as a stable strategy. The recruiting behavior of the ravens is such an example- if the other young ravens did not reciprocate in turn, then the young raven would simply be giving away free resources with no compensation. However, even with simpler organisms cooperation can still be a stable strategy. As shown with the Hawk-Dove theory and the Prisoner's Dilemma, cooperation can be strong simply because it is safer. Even if an individual is sacrificing a part of the resource they could have potentially earned, the elimination of escalating competition from their own species also eliminates risks- and in some environments the elimination of these risks is especially valuable. As depicted by the Selfish-Herd hypothesis, some cooperative behavior can eliminate risks from the environment as well.

Furthermore, cooperation can also pool the collective power of individuals in order to enable a group to yield a higher amount of resources. Animals that hunt in groups, such as wolves or hyenas, are a prime example of this. A lone spotted hyena would have a very difficult time hunting a wildebeest, but with several of its fellow hyena helping it becomes significantly easier. This is not exclusive to predatory behaviors- as shown by the actions of the ravens. If all goes exceptionally well for the recruiting young raven, and its recruiting behavior is reciprocated, the young raven will in the end have access to a greater total amount of carrion across several sites rather than just the king's share of one.

HONEYGUIDE COOPERATION

One thing that Heimrich’s work did not address was that cooperation can also occur between two different species. The greater honeyguide of Africa actually has a very unique cooperative strategy for which it is named. By making distinctive calls to garner a humans attention, these birds will lead humans to bee hives. If the people are native honey-hunters, they will temporarily disable the bees in the hive with smoke, and cut open the hive for honey. After the humans leave, the honeyguide will get the pickings of whatever is left. This behavior is actually rather well studied, especially involving the Boran people of southern Ethiopia (Spottiswoode, Science Magazine). The Boran honey-hunters actually employ a special whistle used solely for honey hunting that alerts the honeyguides that they are on the hunt for honey. This whistle, called the fuulido, has been proven to double the honeyguide encounter rate, as the honeyguides have associated the distinct sound with the launch of their strategy.

As Ethiopian culture evolves, so do the people's interactions with the honeyguides. Because many in Africa now use sugar cane rather than honey, in many areas honey-hunting has become obsolete. Not surprisingly, in these areas, the greater honeyguides strategy of leading humans to hives has died out. It is also worth mentioning that similar to the ravens, this cooperative behavior is seen much more frequently in immature, adolescent honeyguides. Perhaps as the honeyguide grows into its full potential, it becomes more able to take on these hives itself, which would grant a higher resource yield than if it had worked with honey-hunters.

CONCLUSION

Cooperation can be an evolutionarily stable strategy, one of countless methods of survival. As seen in the behavior of the greater honeyguide and the common raven, cooperation can be a successful strategy for both intraspecies and interspecies interactions. In many scenarios cooperation is not a stronger strategy than solitary behaviors, however, as explained by way of Hawk-Dove theory and the Prisoner’s Dilemma, Cooperation can be the mathematical, rational strategy. It is the successful individual that will pass on their genetics and behaviors to the next generation. If cooperation grants an individual more success, it will become prevalent in a given community.

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