humans

MDPI

Hypothesis

Unintentional Evolution: The Rise of Reciprocal Altruism

Sergio Da Silva [1,*] and Sergio Bonini [2]

1 Department of Economics, Federal University of Santa Catarina, Florianopolis 88040-900, Brazil
2 Department of Informatics and Statistics, Federal University of Santa Catarina, Florianopolis 88040-370, Brazil; mrsergiobonini@gmail.com
* Correspondence: professorsergiodasilva@gmail.com

Abstract: In this study, we propose a groundbreaking hypothesis for the evolution of reciprocal altruism, suggesting its emergence from random encounters characterized by theft rather than the traditionally accepted cooperative reciprocation and intertemporal choice. We challenge the conventional theory, critiquing its circular reasoning that presupposes cooperation to explain its own origin. Our approach posits that theft, when passively tolerated during times of abundance, does not negatively impact survival and reproduction. This leads to a novel understanding of cooperation as a form of "tolerated theft". To support our theory, we developed a Python-based simulation model that succinctly demonstrates how this mechanism could operate. Our key finding is that in environments where theft is tolerated, offspring may evolve to overlook such acts, eventually emerging as reliable reciprocators in times of scarcity. This hypothesis, while potentially controversial due to its originality, opens up new perspectives on the accidental evolution of reciprocal altruism and encourages a reevaluation of the fundamental mechanisms driving cooperative behaviors.

Keywords: reciprocal altruism; cooperation; randomness and evolution

check for updates

Citation: Da Silva, S.; Bonini, S. Unintentional Evolution: The Rise of Reciprocal Altruism. *Humans* **2024**, *4*, 22–33. https://doi.org/10.3390/humans4010002

Academic Editor: Haskel J. Greenfield

Received: 24 November 2023
Revised: 11 December 2023
Accepted: 28 December 2023
Published: 31 December 2023

1. Introduction

Understanding the evolution of cooperation in humans presents a challenge. Natural selection typically favors traits that enhance an organism's reproductive success, making sacrifices for others seem costly [1]. An associated question is altruism, which can be explained by inclusive fitness when aiding genetic relatives [2,3]. However, the evolution of altruism among nonrelatives remains perplexing. The prevailing solution is reciprocal altruism theory, suggesting that adaptations for helping nonrelatives can evolve if benefits are reciprocated in the future [4].

A key oversight in this argument is its assumption that trade, especially intertemporal trade, has already developed. Yet, trade becomes possible only after cooperation has already emerged. Therefore, we still lack an explanation for the evolution of reciprocal altruism among self-interested nonrelatives. To address this gap, we propose that randomness can create the conditions for cooperation to thrive during times of abundance, and we support this hypothesis with a computer simulation.

To illustrate the theory of reciprocal altruism, consider this example (adapted from [1]): Two unrelated hunters, not yet friends due to the prior assumption of cooperation, experience erratic hunting success. One succeeds now while the other does not, and vice versa later. Sharing the meat now costs the first hunter in terms of fitness, but he can benefit by preventing meat spoilage and helping the starving other hunter, for whom meat is scarcer and costlier.

The situation similarly favors the other hunter, making an intertemporal exchange mutually beneficial, assuming that they prefer trading over stealing. Both hunters gain more from reciprocal altruism than from selfishly hoarding all of the meat. The idea is that those engaging in reciprocal altruism will have greater reproductive success than purely selfish individuals. However, a flaw in this argument is that exchange can only happen after cooperation has already evolved, rendering the theory of reciprocal altruism circular. Furthermore, the theory faces the challenge of cheating, as there is always a short-term benefit to dishonesty [5]. Since intertemporal benefits and costs are subjective, one hunter could pretend to be a reciprocal altruist by taking the meat now without reciprocating later. To address this, the theory of reciprocal altruism requires additional theorizing to pinpoint specific psychological adaptations that tackle the cheating problem [1]. However, this supplementary theorizing is complex and prone to circular reasoning, given that cooperation's vulnerability to cheating exposes group members to theft [6].

It may be argued that reciprocating strategies are not inherently cooperative, as implied by the theory of reciprocal altruism, but rather that reciprocation is contingent on receiving it first. To address this concern, consider the analogy with the prisoner's dilemma game, where both players can benefit from cooperation but are tempted to exploit their partner's altruism without reciprocating. In a one-shot game, the rational choice is to defect [5]. This unspoken connection with the prisoner's dilemma challenges the core premise of reciprocal altruism, which posits that adaptations for providing benefits to nonrelatives can evolve as long as future reciprocation is expected.

As a response, Axelrod and Hamilton [7] directly tackled this issue by proposing that cooperation is best achieved when players employ a 'tit-for-tat' strategy in repeated games, with no set endpoint—an assumption that is often valid in real-world scenarios. Tit-for-tat's success relies on three key principles, forming the lex talionis [8]: (1) start with cooperation and maintain it as long as others do the same; (2) swiftly switch to defection after the first instance of non-reciprocity; and (3) reciprocate cooperation if a previously defecting player returns to cooperation, creating a mutually beneficial cycle.

We highlight the initial step in which a player starts with cooperation, a premise inherent in the tit-for-tat strategy, sometimes referred to as 'generous' tit for tat [9]. An alternative approach is the Pavlov strategy, which follows the principle of 'win-stay, lose-shift'. While it outperforms generous tit for tat in simultaneous games, it fares poorly in strictly alternating games [10]. It is important to note that the Pavlov strategy, like tit for tat, assumes the presence of psychological adaptations for cooperation in both concurrently acting players from the outset.

To illustrate how randomness can promote cooperation during times of abundance, we establish an environment where selfish hunters engage in violent conflicts rather than trade. The outcomes vary based on game abundance, leading to either success or failure for the hunters. A key aspect of these violent conflicts is the inclusion of tolerated theft, preventing the violence from escalating into murder.

Blurton Jones [11] first introduced the concept of tolerated theft, suggesting that human food sharing, especially among hunters, originates from selfish motives. He posited that sharing large food items within a group is less costly than the alternative of not sharing. This idea aligns with Machiavellian intelligence, which involves the use of complex social strategies for individual benefit within social groups. Complex social strategies, including manipulation and deceit, have evolved to enhance an individual's fitness in social groups. In the case of tolerated theft, individuals engage in seemingly cooperative behavior (sharing) not out of altruism, but as a strategic response to social and environmental conditions, thereby maximizing their own fitness and survival chances.

Our hypothesis, which posits that reciprocal altruism may have evolved from instances of theft in resource-abundant environments, aligns with the idea of tolerated theft from the Machiavellian intelligence framework, which is widely accepted. Machiavellian intelligence enables individuals in a group to hone advanced social skills, allowing them to strategically navigate and manipulate social dynamics for their own benefit. In the context of tolerated theft, individuals initially engaging in theft as a selfish strategy may have inadvertently set the stage for the evolution of reciprocal altruism. This occurs when the cost of defending resources is higher than the cost of tolerating theft, leading to a passive acceptance of theft in certain situations.

In particular, Wilson [12] delineated the transition from individual self-interest to group-level adaptations, where behaviors like food sharing, initially driven by self-interest, evolve into mechanisms benefiting the group, aligning with our theory of accidental cooperation. Furthermore, Schiefenhövel [13] highlighted the evolutionary significance of passive sharing turning into an altruistic act, a notion resonating with our model of theft transforming into cooperation under conditions of abundance. Significantly, the work of Gintis [14] reinforced the shift from tolerated theft in non-human primates to a more structured sharing system in humans, underpinned by fairness norms and moral considerations. This transition marks a pivotal development in human social evolution, aligning with our hypothesis that initial tolerance of theft could inadvertently foster cooperative behaviors.

Existing literature on tolerated theft does not address its connection to the unintended emergence of reciprocal altruism. Our paper provides this insight. However, these perspectives provide a comprehensive backdrop to our theoretical framework, distinguishing our approach while acknowledging the foundational work in this domain. Integrating these insights, we propose that reciprocal altruism, as an unintentional evolutionary outcome, may have stemmed from such rudimentary forms of social interactions, initially driven by individual interests but gradually morphing into complex cooperative systems.

Our simulation results, showing how passive reactions to theft in times of abundance do not significantly harm the survival and reproduction chances of individuals, suggest an evolutionary pathway where Machiavellian strategies could inadvertently lead to cooperative behaviors. In an environment where resources are abundant and the cost of defending them is high, tolerating theft becomes a viable strategy, reducing conflict and potential harm. Over time, this tolerance could evolve into a more structured form of reciprocal altruism, where individuals engage in mutual cooperation, not out of inherent cooperativeness, but as an extended form of self-interest. Our paper's findings thus extend the understanding of Machiavellian intelligence by illustrating how behaviors initially driven by self-interest can, over evolutionary timescales, give rise to social cooperation mechanisms, a foundational aspect of human society.

The coevolution of humans and dogs (*Canis familiaris*) offers a precedent supporting our hypothesis that competition can inadvertently lead to cooperation. Humans have domesticated dogs for over 14,000 years, starting with nomadic hunter-gatherers. Interestingly, humans unintentionally domesticated dogs by sharing excess lean meat with wolves (*Canis lupus*), the ancestors of all modern dogs. During harsh Ice Age winters when food was scarce, humans and wolves, both top predators, initially competed for resources. Wolves can survive on lean meat, while humans require fat and other nutrients due to their omnivorous nature. As humans often had surplus lean meat, wolves benefited from consuming the excess, eliminating the competition. Late Pleistocene hunter-gatherers in Eurasia adopted orphaned wolf puppies and fed them leftover meat, leading to these domesticated wolves becoming valuable hunting companions, reinforcing domestication [15–17]. This historical account illustrates how interspecies competition can unintentionally foster cooperation, a concept extended to interhuman competition in this paper.

Our hypothesis is supported by studies on food-resource partitioning [15]. These suggest that early humans shared excess lean meat with wolves during harsh winters, reducing competition and fostering mutualistic relationships that led to dog domestication. However, alternative theories exist [15], each with varying scientific support: (1) Wolves might have scavenged from human kills or stolen food from camps, potentially leading to coexistence and domestication, especially if early humans, who were largely scavengers, tolerated or indirectly facilitated this. (2) The dietary differences between wolves and humans could have allowed sympatric existence, with wolves consuming lean meat, less suited for humans, thus reducing resource competition. (3) Post-domestication, a coevolution process between humans and dogs, is theorized, possibly leading to shared traits and mutual success. (4) Paleolithic humans may have captured and tamed wolf pups as pets over generations, leading to domestication. There are theories of humans actively taming wolves for hunting or wolves being attracted to human waste zones, but these face challenges considering early human settlement patterns and the diet of early dogs.

It might be argued that for most of human history, scarcity was the prevailing challenge. This perspective suggests that humans evolved to cope with scarcity. However, the notion of "overkill" challenges this view. Near the end of the Pleistocene, around the time of human arrival, approximately 37 genera of large mammals went extinct in North America, with evidence suggesting human hunting as a contributing factor [18]. This implies that there were periods of abundance as well. Without accounting for overkill and denying the existence of abundance, one might argue that during times of scarcity, the trait of "reacting aggressively to theft" should have been favored over "not reacting to theft". It is important to note that both traits have evolved to some extent. While humans are generally pro-social today, we strongly react to theft, even in times of abundance. Similarly, in our interspecies analogy, both wolves and dogs react to theft among themselves. However, our point is that the evolution of the trait of "not reacting to theft" was pivotal in the development of reciprocal altruism from the outset.

2. Experimental Setup

Two hunters independently roam a limited area, capturing game animals that enter randomly. When a hunter spots a deer, they capture it, and if one hunter encounters the other, the stronger one steals the weaker one's meat through violence, reflecting their selfish behavior without any trade.

We adjust the rate of deer entry to assess the hunters' performance. Additionally, when one hunter amasses enough meat to sustain a female partner (set at twice his own survival needs), a cloned offspring hunter appears in the simulation.

All offspring share the same on-screen color as their parents, with female partners omitted for modeling simplicity. In times of scarce game, the original hunters are prone to perish as their vital energy is depleted. Conversely, in times of plenty, they are more likely to survive and reproduce. We selected arbitrary thresholds to underscore the impact of contrasting circumstances on the reproduction of both the initial hunters and their offspring during instances of bonanzas.

Hunters who survive and reproduce are those who tend to passively give away meat in encounters, passing down the trait of not reacting to their descendants. This trait, evolved during abundance, persists in times of game scarcity.

It is important to clarify that this psychological inclination is not a voluntary desire to cooperate and trade, but rather a passive response to theft. Reciprocal altruism evolves from this passivity, not from cooperative behaviors with intertemporal choices. In times of plenty, meat theft does not threaten survival or reproduction, allowing the offspring of selfish hunters to exhibit reciprocal altruism due to fortunate circumstances during prosperity.

The following are the software characteristics used: Python 3.10.12 64-bits; Processor Intel Core i5-9400, CPU@2.90 GHz x6; Memory: 8.0 GiB; Graphics: Mesa Intel@UHD Graphics (CFL GT2); Disk capacity: 1.1 TB.

3. Results

Table 1 presents data from 10 experiments where our model was run 1000 times each. The focus is on the number of instances, out of these 1000 runs, where all hunters perished. Initially, each simulation starts with two hunters. We examine three scenarios: (1) "Default", with a 1/11 chance of deer appearing; (2) "Scarcity", with a deer appearance probability of 1/50; and (3) "Bonanza", where there is a 1/3 probability that deer will appear. As observed, the study also considers the "genetic" success of the hunters, defined as at least one descendant of each original hunter surviving.

Figure 1 indicates that in scarcity scenarios, all hunters perished in 97% of simulations on average. Conversely, in bonanza scenarios, the total hunter fatality rate was just 2% on average. Notably, these results account for the persistent meat-stealing behavior among successive generations of selfish hunters.

Table 1. Impact of varied deer entry probabilities on complete hunter fatality rates.

Probability of Deer Entry	Default: 1/11	Low-Pace: 1/50 Scarcity	Faster-Pace: 1/3 Bonanza
Observations	Frequency of total hunter fatalities in 1000 simulations		
1	445	964	18
2	432	976	25
3	432	971	22
4	439	965	16
5	438	976	11
6	451	968	29
7	435	967	19
8	449	971	20
9	452	968	18
10	444	960	19
Mean	441.7	968.6	19.7
S.D.	7.6	5.1	4.9

Note: All simulations start with two hunters.

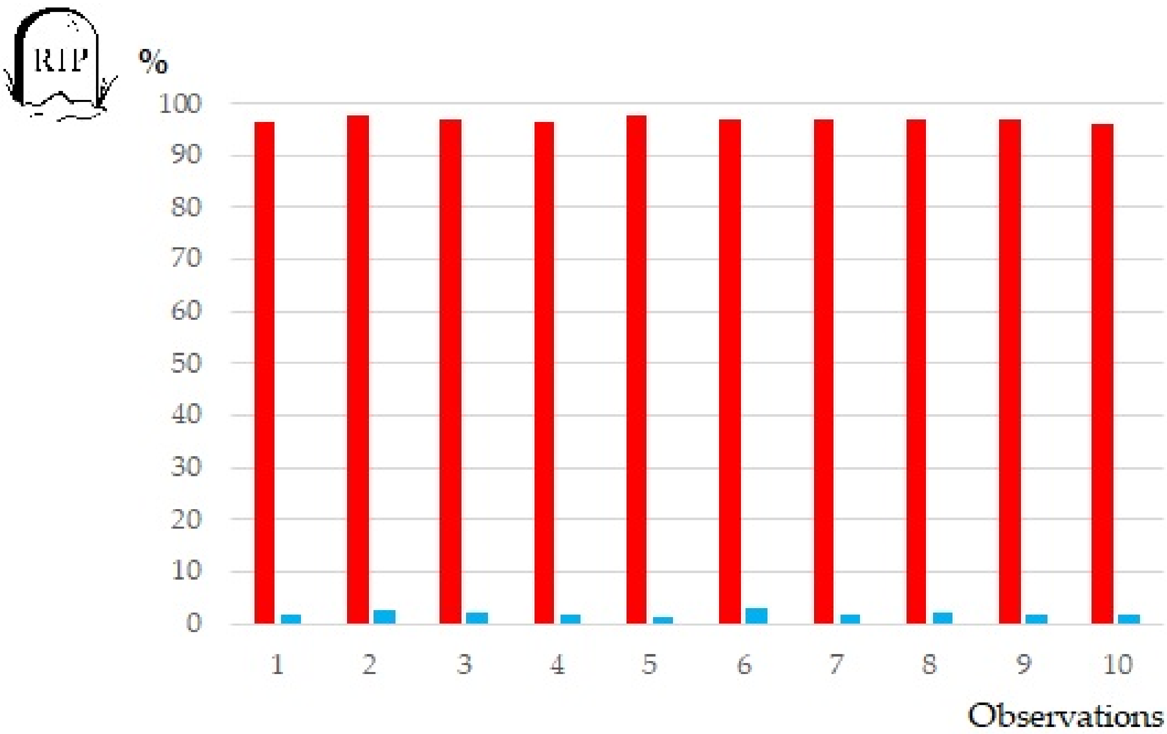

Figure 1. Probability of total hunter fatalities under scarcity and bonanza conditions. Note: Red bars represent scarcity conditions, where, on average, all hunters died in 97% of cases. Blue bars indicate bonanza conditions, under which all hunters died in only 2% of cases on average. Each observation from 1 to 10 in the figure represents the outcome of 1000 separate simulations. Every simulation begins with a starting count of two hunters.

In our simulation, we lack the typical explicit selection mechanism found in evolutionary models. Instead, the simulation illustrates that cooperation, in the form of tolerated theft, arises by chance during times of abundance. Furthermore, since offspring survive, this suggests that cooperation, in the form of tolerated theft, is not actively selected against during harsh times. These findings support our hypothesis (the Python code for the experiment is accessible on Figshare).

A potential simulation development involves assessing scenarios where some hunters passively tolerate theft while others engage in stealing. Although we anticipate this will not impact the outcome, it warrants further exploration. Additionally, we could consider introducing random mutations that affect traits and behaviors.

Our presented survival percentages clearly demonstrate the impact of resource abundance on human behavior and evolution. A potential extension of this work could involve inferring our deer entry probabilities from real-world evolutionary scenarios.

Further research should include additional observations and present simulation results in a table format for easier statistical analysis. Conducting a regression analysis could reveal factors affecting survival rates. Additionally, this method would yield data on the frequency and extent of hunter sharing/cooperation, along with its statistical relationship to survival and reproduction.

The simulation assumed the inheritance of giving behavior in response to increased food supply, but it lacks a specific mechanism. This aspect could be integrated into the simulation design for further detail.

4. Discussion

Many animal species engage in theft and exploitation, suggesting it is a common trait in nature that may drive evolutionary adaptations. Unlike cooperation, theft demands no investment or effort from the thief; it is a swift, low-risk way to acquire resources. If the theft does not directly harm the victim's survival or reproduction, they may not retaliate, allowing the thief to act without consequences. In times of scarcity, having psychological adaptations that overlook theft while still enabling reciprocal altruism can be advantageous for offspring. This allows them to foster cooperative relationships and resource exchange, increasing their chances of survival and reproduction.

To evaluate evidence, theories based on cooperative reciprocation may be preferred over our explanation of passive reactions to theft, because the conventional answer to the altruism problem frequently assumes cooperation to explain cooperation. However, this evidence is typically acquired after cooperation has already developed. It is also arguable that if theft is the primary motivator for reciprocal altruism, it could undermine the trust and reputation essential for long-term cooperation, potentially leading to the dissolution of relationships. In contrast, cooperative reciprocators' actions are rooted in trust, mutual benefits, and sustained collaboration, which tend to endure over time in comparison to sporadic interactions with selfish individuals driven by theft. However, the detrimental impact of theft usually occurs after cooperation has already evolved, not before.

The simulation showed an unexpected shift from competition to cooperation, likely because we examined both encounters between hunters and the connections across multiple generations. Altruism is typically discussed at the individual level, but it is important to recognize that individual, relational, and network factors all contribute to altruistic behavior [19].

Differences among individuals with the same genotype and those they interact with may enhance the passive reaction to theft, potentially promoting reciprocal altruism. This concept is explored in the literature [20]. Passive reactions to theft can be seen as reactive prosocial behaviors involving cooperation [21]. This perspective could clarify the shift from tolerated theft to voluntary sharing and sacrifice, as observed in reciprocal altruism.

Regarding our substitution of intertemporal trade with violent encounters, the existing literature suggests that negotiations between social partners often include a coercive element, regardless of whether a time delay is involved in the exchange or not [22].

Lastly, it is worth noting that prey's random scanning behavior [23], a characteristic in our simulation, can be explored in future research using random walk models and their extensions, such as references [24,25].

5. Conclusions

In our study, we propose a novel perspective on the origins of reciprocal altruism, suggesting it may have emerged unintentionally from passive responses to theft, rather than from deliberate, cooperative intertemporal choices. This idea marks a significant departure from the conventional view that reciprocal altruism stems from calculated reciprocation, a theory which we argue is inherently circular, as it presupposes cooperation to explain its own emergence.

Our research contributes to the field by presenting a clear and focused theoretical rationale, supported by a computer simulation. This simulation demonstrates how, in times of abundance, reciprocal altruism could develop even in the presence of selfish behaviors like widespread meat theft, as these actions do not threaten survival or reproduction. In contrast, during scarcity, our simulation shows the collapse of purely selfish strategies, reinforcing the idea that cooperation can arise fortuitously from non-cooperative contexts.

We suggest that this overlooked mechanism—cooperation as a byproduct of tolerated theft during times of plenty—provides a more plausible explanation for the evolution of reciprocal altruism. It challenges the traditional assumption that intertemporal trade must precede cooperation, suggesting instead that trade becomes feasible only after cooperative behaviors have been established.

Our study brings a fresh perspective to the field, highlighting the importance of considering unintentional pathways in the evolution of complex social behaviors like reciprocal altruism. It invites a reevaluation of existing models and encourages the exploration of alternative, non-intuitive pathways. By addressing the circularity often present in current hypotheses and acknowledging potential theory-induced biases, our research paves the way for more nuanced and comprehensive understandings of the origins and development of cooperative behaviors.

6. Our Hypothesis: Summary and Extensions

6.1. Reconceptualizing Reciprocal Altruism: The Role of Passive Responses and Theft in Evolution

Our hypothesis offers a new perspective on the evolution of reciprocal altruism, contrasting with traditional views that focus on cooperation and mutual benefit. Typically, theories suggest that helping non-relatives evolves through future reciprocation, as seen in strategies like "tit-for-tat" in repeated games. However, our hypothesis suggests reciprocal altruism may have unintentionally developed from random encounters with selfish individuals stealing during times of abundance. Here, passive reactions to theft, not active cooperation, are key.

This idea challenges the usual belief that cooperation is a primary evolutionary trait, proposing instead that it evolved from a tolerance to theft. Empirical studies, like the coevolution of humans and dogs, indirectly support our hypothesis, showing that competition and passive responses to resource sharing can lead to cooperation.

Our hypothesis stands out by assuming random encounters and passive reactions to theft as the starting point for altruism, unlike traditional theories that begin with cooperation or trade. This approach aims to address the circular reasoning in conventional theories that use the existence of cooperation to explain its emergence, offering an alternative origin for altruism that does not initially rely on cooperative intent.

We intriguingly provide a simple but effective methodological approach using a Python simulation to simulate environments of abundance and scarcity. This illustrates how passive reactions to theft can lead to behaviors akin to reciprocal altruism, lending computational support to your theory.

Our hypothesis may be seen as unconventional or even heretical in the context of established theories. However, it offers a fresh perspective that challenges existing beliefs and invites further exploration and debate in the field of evolutionary biology.

6.2. Critiquing Traditional Theories: Introducing an Alternative Origin for Reciprocal Altruism

Our paper reviews dominant theories in evolutionary biology, like Trivers' reciprocal altruism and Axelrod and Hamilton's tit-for-tat strategy. These theories, based on cooperative reciprocation, suggest that helping non-relatives evolves when future benefits are reciprocated. However, we critique these theories for their circular reasoning, as they often presuppose cooperation to explain its existence and struggle with issues like cheating and the assumption that trade and cooperation are prerequisites for altruism.

We introduce a new hypothesis: reciprocal altruism may have unintentionally arisen from passive responses to theft, especially during resource-rich times. This idea challenges traditional theories by proposing an alternative, non-cooperative origin for altruism.

Supporting our hypothesis, we reference empirical studies, like the coevolution of humans and dogs, and use a Python simulation to model different resource conditions. Our approach, focusing on passive responses to theft rather than active cooperation, offers a novel view on the evolution of reciprocal altruism. It encourages rethinking fundamental assumptions in evolutionary biology and emphasizes the potential impact of non-cooperative behaviors and randomness in developing cooperative traits.

6.3. Methodological Approaches to Testing the Theft-Based Altruism Hypothesis

We chose a computer simulation to test our hypothesis on the emergence of reciprocal altruism. However, we propose several alternative methods here:

(1) Enhance our existing simulations to include more complex scenarios, such as different environmental pressures, resource availability, and behavioral strategies. This would deepen our understanding of how passive reactions to theft might evolve into reciprocal altruism.

(2) Conduct observational studies on species known for theft and sharing behaviors, like primates, birds, or domestic animals, to observe how passive reactions to resource theft could develop into cooperative behaviors.

(3) Investigate historical and anthropological records for examples where passive responses to theft or resource sharing in times of abundance led to cooperation, such as in hunter-gatherer societies or early agricultural communities.

(4) Explore the genetic basis of behaviors related to theft and cooperation in humans or animals, looking for genetic markers and how these traits may have evolved in different environments.

(5) Conduct experiments to understand human reactions to theft and sharing under controlled conditions, observing behaviors in scarcity versus abundance.

(6) Use game theory to design experiments that assess decision making in resource allocation, theft, and cooperation under varied conditions.

(7) Track individuals or communities over time to observe the evolution of behaviors related to theft and cooperation.

(8) Investigate how behaviors related to theft and cooperation change in response to environmental shifts, offering insights into human adaptability and social norm evolution.

(9) Explore how different cultures have developed norms around sharing and theft, highlighting the impact of social and environmental factors on cooperative behavior development.

(10) Study the brain's processing of behaviors related to theft and cooperation to understand how these actions are valued differently.

(11) Use insights from evolutionary studies of these behaviors to inform social policies and economic systems that encourage cooperation and resource sharing.

Our hypothesis, therefore, opens multiple avenues for empirical research, offering a new perspective on the evolution of reciprocal altruism and cooperative behavior.

6.4. Challenging Established Theories: Randomness and Passive Responses as Evolutionary Catalysts

Our paper points out a significant flaw in existing theories of reciprocal altruism: they assume pre-existing trade and cooperation, leading to a circular argument. We offer a new hypothesis where randomness, particularly in times of abundance, may spur cooperation, challenging the belief that cooperation is always a conscious, mutually beneficial act.

We reference the coevolution of humans and dogs as an example of how competition between species can unintentionally foster cooperation, a concept applicable to human interactions. Our hypothesis gains further support from a Python simulation that shows how passive reactions to theft in abundant conditions might lead to behaviors resembling reciprocal altruism.

We propose enhancing this simulation by incorporating scenarios where hunters show varying responses to theft and introducing random mutations to affect traits and behaviors. This would provide deeper insights and strengthen our hypothesis.

Our paper also notes a missing element in traditional evolutionary models: a clear mechanism for the selection of cooperation. Our simulation suggests that cooperation, in the form of tolerated theft, could emerge by chance in abundant environments, as an alternative to active selection.

To test our hypothesis, we suggest empirical studies on how different species respond to theft and sharing in various environments. This paper also emphasizes the need to consider individual, relational, and network factors in altruistic behavior, pointing to these as areas for future research into the evolution of altruism.

6.5. Implications of the Theft-Based Altruism Hypothesis across Disciplines

Our hypothesis suggests a new evolutionary pathway for cooperation, proposing that passive reactions to theft in abundant times could lead to reciprocal altruism. This challenges the conventional idea of deliberate cooperation, suggesting it might arise unintentionally.

This focus on randomness and passive responses as catalysts for evolution could transform our understanding of human evolution, highlighting the role of non-adaptive, chance traits. It offers a fresh perspective on the origins of prosocial behaviors, potentially influencing psychological theories on altruism and the balance between selfish and altruistic tendencies. Our hypothesis implies that human decisions in different environments (abundance vs. scarcity) may be more environmentally influenced than consciously made.

Economically, this could suggest that trade and cooperative behaviors evolved from less structured beginnings, impacting theories and social policies aimed at encouraging cooperation, especially in resource distribution and welfare.

Anthropologically, it could reveal how various cultures developed distinct approaches to cooperation, theft, and resource sharing, and help us to understand group dynamics, including the evolution of theft-management mechanisms leading to complex social structures.

In biology and genetics, this hypothesis could lead to research on the genetic basis of passive responses to theft and cooperation. It could also inspire new game theory and behavioral economics models, incorporating randomness and passive behaviors in cooperative strategy development.

Future research could include empirical studies in human societies and animal behavior, promoting interdisciplinary research across evolutionary biology, psychology, economics, and anthropology, to validate this hypothesis.

6.6. Enhancing Simulations to Explore Theft Tolerance and Cooperative Evolution

Our work focused on the dynamics of reciprocal altruism and social interactions in a resource-sharing setting, using a simulation to examine how "tolerated theft" influences offspring survival. This situation can be compared to "non-tolerated theft", in which theft carries consequences. We can even think of an expansion in which it is simulated to eliminate thieves in order to monopolize resources. These extensions may deepen our knowledge of the evolutionary strategies used in social cooperation and resource competition.

Furthermore, to improve our simulation for a more comprehensive analysis, we propose the following enhancements:

(1) Replace fixed resource intervals with variable rates, better reflecting real-world resource unpredictability and simulating theft reactions in dynamic environments.

(2) Add a range of hunter behaviors, including different theft tolerance levels, various resource acquisition strategies (like theft, sharing, hoarding), and adaptive responses based on past interactions.

(3) Implement mutations affecting traits and behaviors to allow the emergence of new strategies across generations, exploring their evolution under different environmental pressures.

(4) Incorporate elements of forming alliances or groups to examine how these dynamics affect individual behaviors and the evolution of reciprocal altruism.

(5) Include precise fitness measures, such as the reproductive success of successful hunters, measured by their ability to attract mates and produce offspring inheriting a combination of parental traits.

(6) Add factors like seasonal or climate changes to test hunter adaptability in varying resource conditions.

Our current simulation, featuring two hunters in an environment with fluctuating game abundance, centers on theft and passive reactions to theft. Survival and reproductive success are key metrics, with survival rates dropping in scarcity and increasing in abundance. Importantly, hunters who passively tolerate theft tend to perform better in abundant conditions.

These results support our hypothesis that passive reactions to theft, as opposed to active cooperation, might be a key factor in the evolution of reciprocal altruism. The simulation's absence of a specific cooperation selection mechanism suggests these behaviors could naturally arise from environmental factors and individual interactions.

By assessing scenarios with diverse hunter reactions to theft, we aim to gain deeper insights and rigorously test our hypothesis in more complex conditions.

6.7. Identifying Flaws in Conventional Theories of Reciprocal Altruism

Our hypothesis challenges traditional reciprocal altruism theories, like those by Trivers, Axelrod, and Hamilton, which base cooperation on reciprocation and mutual benefits. We propose that passive reactions to theft might have been the initial step toward cooperation, highlighting a key flaw in existing theories: their circular reasoning. These theories often presuppose cooperation to explain its emergence, while our hypothesis offers an alternative origin for altruism.

We emphasize the impact of environmental abundance on human behavior, contrasting with the traditional emphasis on scarcity driving evolutionary changes. Our Python simulation demonstrates that in abundant environments, passive reactions to theft can lead to reciprocal altruism-like behaviors.

The coevolution of humans and dogs, as discussed in our paper, provides indirect empirical support. This example shows how interspecies competition and resource sharing can lead to cooperation, a concept applicable to human interactions.

Our theory suggests that cooperation may have evolved as a secondary trait from an initial tolerance of theft, potentially reshaping our understanding of human psychology, especially in how we respond to theft and resource sharing. This new mechanism for the evolution of cooperative behaviors could inspire new research in evolutionary biology.

In psychology, our hypothesis could lead to studies on human responses to theft and cooperation, while in sociology, it might prompt a reassessment of the development of social structures and norms. Enhancing the simulation with more variables and complex interactions, and conducting empirical studies in anthropology and psychology could provide deeper insights and validate our hypothesis.

6.8. Revolutionizing the Understanding of Altruistic Behavior Evolution

Our hypothesis presents a significant challenge to conventional views on altruistic behavior evolution, proposing an alternative, less intentional path. Key aspects of our work include:

(1) We address the circular reasoning in traditional reciprocal altruism theories by suggesting that cooperation might originate from passive reactions to theft in times of abundance, offering a fresh perspective.

(2) We focus on the role of environmental abundance, rather than scarcity, in shaping altruistic behaviors. This marks a notable shift, underscoring the previously overlooked influence of environmental contexts on evolutionary processes.

(3) Our simulations model environments of abundance and scarcity, demonstrating an original approach to support our hypothesis.

(4) Our hypothesis implies that cooperative behaviors in humans and potentially other species may have evolved in a more intricate and indirect manner than traditionally believed, affecting our understanding of human psychology, sociology, and social structure formation.

(5) This hypothesis sets the stage for new empirical and theoretical research, raising questions about the evolution of cooperative behaviors and the impact of environmental factors and random encounters on evolutionary paths.

Author Contributions: S.D.S. conceived the study and wrote the paper; S.B. performed the computational experiment. All authors have read and agreed to the published version of the manuscript.

Funding: This work is supported by CNPq [Grant number: PQ 2 301879/2022-2] and Capes [Grant number: PPG 001].

Informed Consent Statement: Not applicable.

Data Availability Statement: The code can be found here: https://doi.org/10.6084/m9.figshare.24782307.v1 (accessed on 24 November 2023).

Conflicts of Interest: The authors have no conflicts of interest to disclose. The funders were not involved in the study's design, data collection, analysis, manuscript writing, or the decision to publish the results.

References

1. Buss, D.M. *Evolutionary Psychology: The New Science of the Mind*, 6th ed.; Routledge: New York, NY, USA, 2019.
2. Hamilton, W.D. The genetical evolution of social behavior, I. *J. Theor. Biol.* **1964**, *7*, 1–16. [CrossRef] [PubMed]
3. Hamilton, W.D. The genetical evolution of social behavior, II. *J. Theor. Biol.* **1964**, *7*, 17–52. [CrossRef] [PubMed]
4. Trivers, R.L. The evolution of reciprocal altruism. *Q. Rev. Biol.* **1971**, *46*, 35–57. [CrossRef]
5. Krams, I.; Kokko, H.; Vrublevska, J.; Āboliņš-Ābols, M.; Krama, T.; Rantala, M.J. The excuse principle can maintain cooperation through forgivable defection in the Prisoner's Dilemma game. *Proc. R. Soc. B* **2013**, *280*, 20131475. [CrossRef] [PubMed]
6. Neuberg, S.L.; DeScioli, P. Prejudices: Managing perceived threats to group life. In *The Handbook of Evolutionary Psychology*, 2nd ed.; Buss, D.M., Ed.; Wiley: New York, NY, USA, 2016; Volume 2, pp. 704–721.
7. Axelrod, R.; Hamilton, W.D. The evolution of cooperation. *Science* **1981**, *211*, 1390–1396. [CrossRef] [PubMed]
8. Axelrod, R. *The Evolution of Cooperation*; Basic Books: New York, NY, USA, 1984.
9. Nowak, M.A.; Sigmund, K. The alternating prisoner's dilemma. *J. Theor. Biol.* **1994**, *168*, 219–226. [CrossRef]
10. Wedekind, C.; Milinski, M. Human cooperation in the simultaneous and the alternating prisoner's dilemma: Pavlov versus generous tit-for-tat. *Proc. Natl. Acad. Sci. USA* **1996**, *93*, 2686–2689. [CrossRef]
11. Blurton Jones, N. A selfish origin for human food sharing: Tolerated theft. *Ethol. Sociobiol.* **1984**, *5*, 1–3. [CrossRef]
12. Wilson, D.S. Hunting, sharing, and multilevel selection: The tolerated-theft model revisited. *Curr. Anthropol.* **1998**, *39*, 73–97. [CrossRef]
13. Schiefenhövel, W. On the human ethology of food sharing. *Anthropol. Rev.* **2014**, *77*, 355–370. [CrossRef]
14. Gintis, H. The evolutionary roots of human hyper-cognition. *J. Bioecon.* **2013**, *15*, 83–89. [CrossRef]
15. Lahtinen, M.; Clinnick, D.; Mannermaa, K.; Salonen, J.S.; Viranta, S. Excess protein enabled dog domestication during severe Ice Age winters. *Sci. Rep.* **2021**, *11*, 7. [CrossRef] [PubMed]
16. Gojobori, J.; Arakawa, N.; Xiayire, X.; Matsumoto, Y.; Matsumura, S.; Hongo, H.; Ishiguro, N.; Terai, Y. The Japanese wolf is most closely related to modern dogs and its ancestral genome has been widely inherited by dogs throughout East Eurasia. *bioRxiv* **2021**. [CrossRef]
17. Shipman, P. *Our Oldest Companions: The Story of the First Dogs*; Harvard University Press: Cambridge, MA, USA, 2021.
18. Wolfe, A.L.; Broughton, J.M. A foraging theory perspective on the associational critique of North American Pleistocene overkill. *J. Archaeol. Sci.* **2020**, *119*, 105162. [CrossRef]
19. Curry, O.; Dunbar, R.I.M. Altruism in networks: The effect of connections. *Biol. Lett.* **2011**, *7*, 651–653. [CrossRef] [PubMed]
20. Fletcher, J.A.; Doebeli, M. A simple and general explanation for the evolution of altruism. *Proc. R. Soc. B* **2009**, *276*, 13–19. [CrossRef]
21. Jaeggi, A.V.; Burkart, J.M.; Van Schaik, C.P. On the psychology of cooperation in humans and other primates: Combining the natural history and experimental evidence of prosociality. *Phil. Trans. R. Soc. B* **2010**, *365*, 2723–2735. [CrossRef]
22. Taborsky, M.; Frommen, J.G.; Riehl, C. Correlated pay-offs are key to cooperation. *Phil. Trans. R. Soc. B* **2016**, *371*, 20150084. [CrossRef]
23. Scannell, J.; Roberts, G.; Lazarus, J. Prey scan at random to evade observant predators. *Proc. R. Soc. Lond. B* **2001**, *268*, 541–547. [CrossRef]

24. Codling, E.A.; Plank, M.J.; Benhamou, S. Random walk models in biology. *J. R. Soc. Interface* **2008**, *5*, 813–834. [CrossRef]
25. Sakiyama, T.; Gunji, Y.P. Emergence of an optimal search strategy from a simple random walk. *J. R. Soc. Interface* **2013**, *10*, 20130486. [CrossRef] [PubMed]