

# Experimental evidence suggests that high-ranked individuals exploit low-ranked ones but cooperate more within a competitive hierarchy

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Cooperation is one of the fundamental pillars on which today's society is based. Nevertheless, conflicts are present in every aspect of human life and arise from group-living and competition for resources. Generally, these conflicts lead to dominance-subordination relationships called hierarchies. Cooperation is understood as the collective effort made by a group of individuals—whether being people or animals—to achieve a common goal [1]. Societies organize in a hierarchy when some individuals have preferential access to specific resources. These hierarchies exist in both large systems, from world politics [2] to news coverage [3], as well as in smaller systems such as faculty hiring networks [4] and healthcare professionals [5]. Furthermore, hierarchies are not exclusive to humans but are also present in many social animals [6], where the most common observed structure is a linear hierarchy [7].

Yet, the specific mechanisms that produce and maintain hierarchies remain unclear. Two main hypotheses have been proposed: i) they are due to intrinsic attributes of the individuals; ii) they are due to the social interaction dynamics [8]. Some pioneering mathematical models [9] suggest that dominance orders could simply result from a self-organizing process: winners increase their probability of winning, and losers reinforce theirs of losing. Additionally, some agent-based models [10] show that the double reinforcement mechanism may cause an egalitarian society to transform into a hierarchical one when the intensity of conflicts increases.

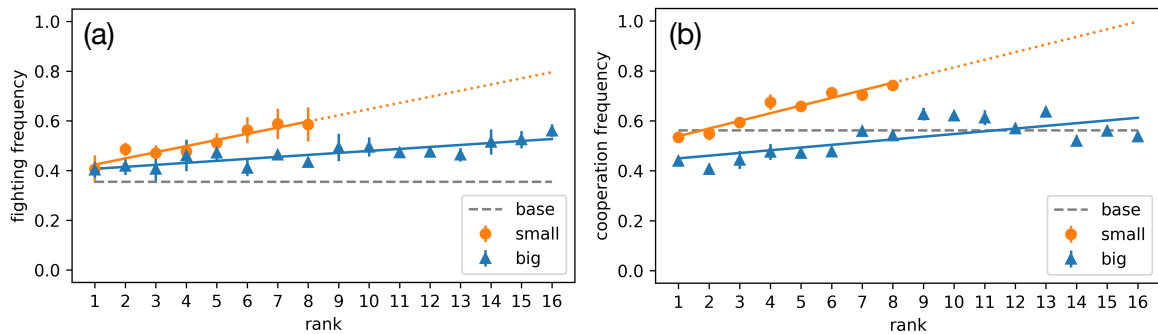
The relationship between hierarchies and cooperation is an open and important problem, since some initial experimental evidence suggests that steep hierarchies lead to low cooperation [11] and that less steep hierarchies can preserve it [12]. Other theoretical analyses show that high-ranked individuals can act seemingly altruistically in between-group conflicts [13]. Consequently, an open question remains: how can large-scale cooperative societies arise if a strong, detrimental-for-cooperation hierarchical structure is present?

To address this question, we created an agent-based model and tested it within behavioral experiments that shed us some insights on how humans behave under these circumstances [14, 15]. The model [14] represents early human groups characterized by their egalitarian societies, combining the ideas of conflicts—through fighting over resources obtained from collective action problems—and then feeding back the results into a hierarchical structure where social norm internalization increases the cooperation level.

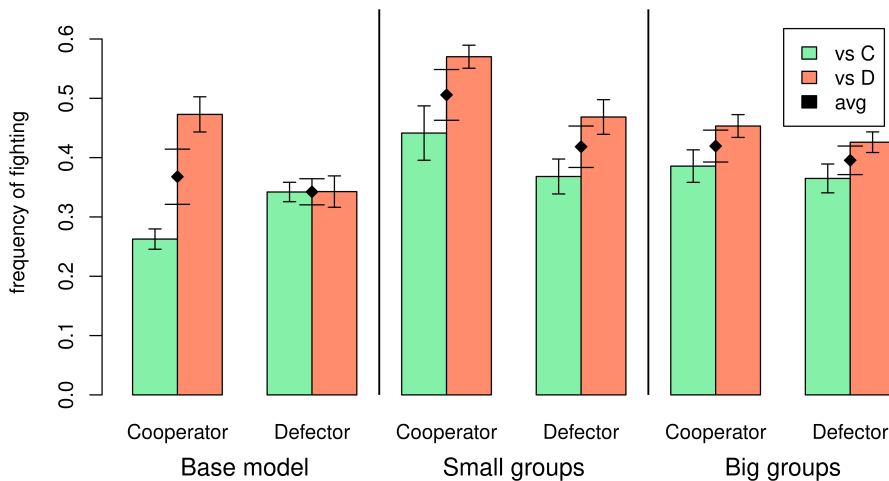
To test the hypotheses inferred from the model, we developed three experimental treatments resembling our setup from [14]. Each individual begins with the same rank that represents her position within the group (egalitarian society). At each experimental round, individuals participate in two subsequent stages. In the first stage, individuals choose to cooperate or not with their group-mates in a collective action problem—a classic public goods game—to obtain a resource. In the second stage, individuals have the opportunity to fight another paired group-mate over the resources obtained in the previous stage. Individuals can choose if they want to fight the other, randomly chosen individual, from whom they can see her rank and if she cooperated in the current round. From these conflicts, a winner and a loser arise: the higher the rank, the more probable it is to win. Consequently, the winner increases her rank while the loser decreases it. Treatments considered different group sizes  $n$  (base,  $n = 8$ ; small,  $n = 8$ ; and big,  $n = 16$ ) and different information provided to the participants: the ranking had no influence in the base model, and it was not shown.

In our model [14], a hierarchy can arise in a cooperative society, which contrasts with the experimental observation in [11] that hierarchies might be detrimental for cooperation. However, this insight is consistent with the fact that cooperation is compatible with societies where rankings exist [16]. The difference with previous models can be the key feature for the co-existence of hierarchy and cooperation: the dynamic character of the former. By changing positions in the hierarchy, cooperative behavior changes depending on the subjects' ranking. Another model feature is the internalization of a norm favoring cooperation, where the model aligns with recent work [17] showing that societies developed in regions where agriculture, i.e., solving the collective action problem, was practiced for longer, had more time for norms to emerge while conflicts were more intense, thus creating a stronger selection pressure.

In our behavioral experiments, we observed that individuals occupying high positions within the hierarchy choose to fight more frequently than their counterparts in the bottom, see Fig. 1a. They use their position to engage more often in fights and win them. Surprisingly, they also cooperate more than the individuals in the lower part of the hierarchy see Fig. 1b. Finally, analyzing fighting frequencies separated by behavior, we notice that individuals are biased: they choose to fight more often against defectors, see Fig. 2. Therefore, we recognize an intrinsic feeling of justice where those who do not contribute to a collective action are punished more frequently through the conflict.



**Figure 1. Experimental results by individual ranks.** When a hierarchy is present, more conflicts are observed. High-ranked individuals choose to fight (a) and cooperate (b) more often than low-ranked ones.



**Figure 2. Experimental results by individual behavior.** On average, defectors are chosen to be fought more often when a hierarchy is in act.

## References

- [1] K. A. Cronin and A. Sánchez. “Social Dynamics and Cooperation: The Case of Nonhuman Primates and its Implications for human Behavior”. en. *Advances in Complex Systems* 15.suppl01 (June 2012), p. 1250066.
- [2] J. B. Mattern and A. Zarakol. “Hierarchies in World Politics”. *International Organization* 70.3 (2016). Ed. by R. Adler-Nissen et al., pp. 623–654.
- [3] I. Himelboim, T.-K. Chang, and S. McCreery. “International Network of Foreign News Coverage: Old Global Hierarchies in a New Online World”. en. *Journalism & Mass Communication Quarterly* 87.2 (June 2010), pp. 297–314.
- [4] A. Clauset, S. Arbesman, and D. B. Larremore. “Systematic inequality and hierarchy in faculty hiring networks”. en. *Science Advances* 1.1 (Feb. 2015), e1400005.
- [5] E. Gergerich, D. Boland, and M. A. Scott. “Hierarchies in interprofessional training”. *Journal of Interprofessional Care* 33.5 (Sept. 2019), pp. 528–535.
- [6] G. Theraulaz et al. “Patterns of agonistic interactions in three species of macaques (*Macaca mulatta*, *M. fascicularis*, *M. tonkeana*)”. *Ethology* 91 (1992), pp. 177–202.
- [7] I. D. Chase. “The sequential analysis of aggressive acts during hierarchy formation: an application of the ‘jigsaw’ puzzle approach”. *Anim. Behav.* 33 (1985), pp. 86–100.
- [8] I. D. Chase et al. “Individual differences versus social dynamics in the formation of animal dominance hierarchies”. *Proc. Natl. Acad. Sci. USA* 99 (2002), pp. 5744–5749.
- [9] J. Beacham. “Models of Dominance Hierarchy Formation: Effects of Prior Experience and Intrinsic Traits”. *Behaviour* 140.10 (2003), pp. 1275–1303.
- [10] C. K. Hemelrijk. “Self-organization and natural selection in the evolution of complex despotic societies”. *Biological Bulletin* 202 (2002), pp. 283–288.
- [11] K. A. Cronin et al. “Hierarchy is Detrimental for Human Cooperation”. en. *Scientific Reports* 5.1 (Nov. 2016).
- [12] A. Antonioni et al. “Collaborative hierarchy maintains cooperation in asymmetric games”. *Sci. Rep.* 8 (2018), p. 5375.
- [13] L. Perry and S. Gavrilets. “Foresight in a Game of Leadership”. en. *Scientific Reports* 10.1 (Feb. 2020), p. 2251.
- [14] P. Lozano, S. Gavrilets, and A. Sánchez. “Cooperation, social norm internalization, and hierarchical societies”. en. *Scientific Reports* 10.1 (Sept. 2020), p. 15359.
- [15] P. Lozano, A. Antonioni, and A. Sánchez. “Experimental evidence suggests that high-ranked individuals exploit low-ranked ones but cooperate more within a competitive hierarchy”. *Under Review* (2021).
- [16] S. Gavrilets and P. J. Richerson. “Collective action and the evolution of social norm internalization”. en. *Proceedings of the National Academy of Sciences* 114.23 (June 2017), pp. 6068–6073.
- [17] T. E. Currie, P. Turchin, and S. Gavrilets. *History of agriculture and intensity of warfare shaped the evolution of large-scale human societies in Afro-Eurasia*. preprint. SocArXiv, Feb. 2019.