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NOTICES

PUBLICATION ALERTS

If you have had a paper or book published, or you see something which would be of interest to the group, please send me a publication alert so that I can include it in the newsletter. Many thanks to those who have already sent in alerts.

If there is a journal you feel I should be tracking on a regular basis, let me know.

And if you have any other ideas for extending the “EAORC experience”, please contact me.

ACADEMIA.EDU – Modeling the Past: The Paleoethnological Evidence

In W. Henke & I Tattersall (eds.), Handbook of Paleoanthropology, Springer-Verlag (2nd edition 2015).

PAOLO BIAGI – Modeling the Past: The Paleoethnological Evidence

This chapter considers the earliest Paleolithic, Oldowan (Mode 1), and Acheulean (Mode 2) cultures of the Old Continent and the traces left by the earliest hominids since their departure from Africa. According to the most recent archaeological data, they seem to have followed two main dispersal routes across the Arabian Peninsula toward the Levant, to the north, and the Indian subcontinent, to the east. According to recent discoveries at Dmanisi in the Caucasus, the first Paleolithic settlement of Europe is dated to some 1.75 Myr ago, which indicates that the first “out of Africa” took place at least slightly before this date. The data available for Western Europe show that the first Paleolithic sites can be attributed to the period slightly before 1.0 Myr ago. The first well-defined “structural remains” so far discovered in Europe are those of Isernia La Pineta in Southern Italy, where a semicircular artificial platform made of stone boulders and animal bones has been excavated. The first hand-thrown hunting weapons come from the site of Schöningen in north Germany, where the first occurrence of wooden spears, more than 2 m long, has been recorded from a site attributed to some 0.37 Myr ago. Slightly later began the regular control of fire. Although most of the archaeological finds of these ages consist of chipped stone artifacts, indications of art seem to be already present in the Acheulean of Africa and the Indian subcontinent.

https://www.academia.edu/10364341/P_Biagi_2015_Modeling_the_Past_The_Paleoethnological_Evidence

ACADEMIA.EDU – First Settlement of the Iberian Peninsula in the European Context

In A. de Lomber Hermida and R. Fabregas Valcarce (eds.), To the West of Spanish Cantabria: the Palaeolithic Settlement of Galicia. British Archaeological Reports International Series (2011).

XOSÉ PEDRO RODRÍGUEZ – The First Settlement of the Iberian Peninsula in the European Context

During the last years researchers have debated about when the settlement of Europe took place. The sites of the Iberian Peninsula have provided information that allows us to affirm that humans arrived to Europe more than one million years ago. In Gran Dolina site (Sierra de Atapuerca, Burgos) we have found fauna, lithic artifacts and human remains (*Homo antecessor*) dating about 800,000 years ago. In Fuente Nueva 3 and Barranco León 5 (Granada) faunal remains and lithic artifacts with a chronology of 1,3 million years have been recovered. In addition there are isolated findings in river terraces of the Northwest, Center and South of the Iberian Peninsula that are less conclusive. In the rest of Europe, human occupation during the Lower Pleistocene has also been documented in Italy, France and England. Almost all lithics recovered in these lower Pleistocene sites belong to the technical Mode 1. Mode 2 technology appears clearly around 600,000 years ago, related to *Homo heidelbergensis*. The discussion is raised about the rupture or continuity at technological and biological level between the end of the Lower Pleistocene and the beginning of the Middle Pleistocene.

https://www.academia.edu/2324569/Rodr%C3%ADguez_X_P_2011_First_Settlement_of_the_Iberian_Peninsula_in_the_European_Context

ACADEMIA.EDU – The Early Acheulian of north-western Europe

In Journal of Anthropological Archaeology 40, 302-331 (2015).

MARIE-HELENE MONCEL et al – The Early Acheulian of north-western Europe

The introduction of biface technology in the Lower Palaeolithic arguably marked a fundamental change in how early hominins dealt with their world. It is suggested to reflect changes not just in tool form and innovative shaping, but also in planning depth, landscape use and social structures. This paper examines in detail the chronology of the first Acheulian industries in north-west Europe with the earliest sites from c. 700ka through to later sites at c. 400ka. It asks whether evidence from these sites can further our understanding of how the Acheulian and the bifacial technology emerged in this region, but more critically whether it was the underlying behavioural changes that enabled the more sustained occupation of northern latitudes. In particular the paper assesses whether cultural signatures can be identified and whether this reflects

changes in group dynamics and social structures that could be a fundamental aspect of surviving in more seasonal, cooler climates. To achieve this, the industries are examined in their chronological and biogeographical framework and compared over time and with the south European sites. The study discusses the influencing factors on variability such as raw material, site function, palaeogeography and questions regarding the background conditions for the introduction of the bifacial technology in Europe. The flexibility in behaviour makes the identification of cultural traditions across Europe difficult due to the situational responses of the early hominins. The large geographical area, the long time period, the fragmented record, and a chronology that still needs improvement all mean that only glimpses of traditions can be identified, usually at a very local level. However, due to the more extreme climatic cycles of northern Europe, compared to southern Europe, it seems inevitable that populations colonized repeatedly from south to north as climate warmed and retreated or populations became locally extinct as climate cooled. Although there are broad similarities in technology, attempts to identify cultural links have been hampered by the greater variety of raw materials in the south compared to the generally better quality siliceous raw materials in the north. Broad patterns over time might be discernible, with perhaps a refinement through time, but there are also many exceptions to this observation. What seems clearer are other technological innovations from 600 to 500ka that seem part of an Acheulian package and might reflect other changes in human cultures and societies. It is suggested that these developments were a critical part of more sustained occupation of northern latitudes.

https://www.academia.edu/18024976/Early_Acheulian_of_north_western_Europe

ACADEMIA.EDU – The Acheulian of Western Europe

*In N. Goren-Inbar and G. Sharon (eds.), **Axe Age: Acheulian Toolmaking from Quarry to Discard**. Equinox Publishers, London (2006).*

MANUEL SANTONJA & PAOLA VILLA – The Acheulian of Western Europe

In the current state of knowledge, the European distribution of Acheulian industries that include handaxes and cleavers appears to be centered in southwestern Europe; their maximum northward expansion reaches England and Germany. North of latitude 52° and east of Germany and Italy, handaxe industries are conspicuously absent, occurring only sporadically in southeastern Europe. Handaxe industries are again well documented in western Asia, from Georgia to Israel and the Arabian Peninsula, clearly indicating an East African origin. The gap between eastern and western Eurasia and the high density of finds in the Iberian Peninsula suggests that the Acheulian in southwestern Europe may derive from the Maghreb, notwithstanding the lack of direct evidence for the crossing of the Straits of Gibraltar. In the Spanish Meseta the geological formations containing Acheulian industries are dated to the time range of OIS 11 to 6. The chronological gap between the earlier human occupation sites at Gran Dolina and in the Orce region and the Spanish Acheulian (an interval of about 300–400,000 years) would seem to reflect an earlier settlement in warm-temperate Europe that did not take a strong hold. The distribution of cleavers coincides only partly with that of Acheulian handaxes. Cleavers are most abundant in regions in which the raw material occurs in the form of large quartzite cobbles that do not need extensive decortication and shaping prior to the removal of large flakes, as in the Spanish Meseta and the Garonne and Tarn valleys of southwestern France. Elsewhere (northern France, England, Italy), cleavers also occur in different raw materials (flint or limestone) but are not common. In Spain, the transition from Acheulian industries to assemblages characterized by the Levallois method without large cutting tools may be as old as 300 ka, based on the age of stratigraphic units TD 10 and 11 at Gran Dolina. However, the evidence from open-air sites suggests a possible coexistence of industries traditionally called Upper Acheulian and others included in the Mousterian complex up to the end of the Middle Pleistocene. In northern France and adjacent countries (Belgium, the Netherlands), assemblages containing rare bifaces and Levallois debitage occur during OIS 8, broadly contemporaneous with assemblages containing bifaces and non-Levallois debitage. The Levallois method is well documented from OIS 7 onward.

https://www.academia.edu/28895208/The_Acheulian_of_Western_Europe

OTHER PUBLICATIONS – Speech naturalness detection and language representation in the dog brain

*In **NeuroImage**, Available online 12 December 2021, 118811 (2021).*

LAURA V. CUAYA et al – Speech naturalness detection and language representation in the dog brain

Family dogs are exposed to a continuous flow of human speech throughout their lives. However, the extent of their abilities in speech perception is unknown. Here, we used functional magnetic resonance imaging (fMRI) to test speech detection and language representation in the dog brain. Dogs (n = 18) listened to natural speech and scrambled speech in a familiar and an unfamiliar language. Speech scrambling distorts auditory regularities specific to speech and to a given language, but keeps spectral voice cues intact. We hypothesized that if dogs can extract auditory regularities of speech, and of a familiar language, then there will be distinct patterns of brain activity for natural speech vs. scrambled speech, and also for familiar vs. unfamiliar language. Using multivoxel pattern analysis (MVPA) we found that bilateral auditory cortical regions represented natural speech and scrambled speech differently; with a better classifier performance in longer-headed dogs in a right auditory region. This neural capacity for speech detection was not based on preferential processing for speech but rather on sensitivity to sound naturalness. Furthermore, in case of natural speech, distinct activity patterns were found for the two languages in the secondary auditory cortex and in the precruciate gyrus; with a greater difference in responses to the familiar and unfamiliar languages in older dogs, indicating a role for the amount of language exposure. No regions represented differently the scrambled versions of the two languages, suggesting that the activity difference between languages in natural speech reflected sensitivity to language-specific regularities rather than to spectral voice cues. These

findings suggest that separate cortical regions support speech naturalness detection and language representation in the dog brain.

<https://www.sciencedirect.com/science/article/pii/S105381192101082X>

NEWS

SCIENCE DAILY – Anthropologists study the energetics of uniquely human subsistence strategies

Among our closest living relatives -- the great apes -- we humans are unique: We have larger brains, reproduce more quickly and have longer life spans. These traits are obviously valuable, but the extra energy required to sustain them is quite significant. So how did we manage to afford them?

<https://www.sciencedaily.com/releases/2022/01/220103145553.htm>

SCIENCE DAILY – How a brain network enables human conversation

A new study has identified a brain circuit that is active while we plan our spoken replies during conversation. The work promises to guide the design of new therapies for the 7.5 million Americans who have trouble using their voices, say the study authors.

<https://www.sciencedaily.com/releases/2022/01/220105134518.htm>

SCIENCE DAILY – How the brain's blue spot helps us focus our attention

How can we shift from a state of inattentiveness to one of highest attention? The locus coeruleus, literally the 'blue spot,' is a tiny cluster of cells at the base of the brain. As the main source of the neurotransmitter noradrenaline, it helps us control our attentional focus. Synthesizing evidence from animal and human studies, scientists have now developed a novel framework describing the way the blue spot regulates our brain's sensitivity to relevant information in situations requiring attention.

<https://www.sciencedaily.com/releases/2022/01/220107121453.htm>

SCIENCE DAILY – Why people deceive themselves

A philosophy team analyzed the role self-deception plays in everyday life and the strategies people use to deceive themselves. The team described four strategies used to stabilize and shield the positive self-image. According to their theory, self-deception helps people to stay motivated in difficult situations.

<https://www.sciencedaily.com/releases/2022/01/220107100652.htm>

SCIENCE NEWS – Renowned paleoanthropologist, conservationist Richard Leakey dies

“Visionary touch” strengthened Kenyan science.

<https://www.science.org/content/article/renowned-paleoanthropologist-conservationist-richard-leakey-dies>

SCIENCE NEWS – The natural world loses two of its biggest advocates

A love of animals led Edward O. Wilson and Thomas Lovejoy to define and defend biodiversity—in very different ways.

<https://www.science.org/content/article/natural-world-loses-two-its-biggest-advocates>

THE CONVERSATION – Curious Kids: why didn't other creatures evolve the intelligence humans have?

Having intelligence helps humans survive.

<https://theconversationuk.cmail19.com/t/r-l-trhhditt-khhilillah-x/>

OTHER NEWS – GUARDIAN – Africa's heritage is humanity's – and it's been overlooked for too long

As an archaeologist, I am hoping my new project will connect the continent's people to the hidden history of their land.

<https://www.theguardian.com/commentisfree/2022/jan/03/africa-humanity-heritage-archaeologist>

PUBLICATIONS

Biology Letters

PAPERS

CHRISTOPH J. VÖLTER & LUDWIG HUBER – Dogs' looking times and pupil dilation response reveal expectations about contact causality

Contact causality is one of the fundamental principles allowing us to make sense of our physical environment. From an early age, humans perceive spatio-temporally contiguous launching events as causal. Surprisingly little is known about causal perception in non-human animals, particularly outside the primate order. Violation-of-expectation paradigms in combination with eye-tracking and pupillometry have been used to study physical expectations in human infants. In the current study, we establish this approach for dogs (*Canis familiaris*). We presented dogs with realistic three-dimensional animations of launching events with contact (regular launching event) or without contact between the involved objects. In both conditions,

the objects moved with the same timing and kinematic properties. The dogs tracked the object movements closely throughout the study but their pupils were larger in the no-contact condition and they looked longer at the object initiating the launch after the no-contact event compared to the contact event. We conclude that dogs have implicit expectations about contact causality.

<https://royalsocietypublishing.org/doi/full/10.1098/rsbl.2021.0465>

R. JEFFREY MARTIN et al – No evidence for future planning in Canada jays (*Perisoreus canadensis*)

In the past 20 years, research in animal cognition has challenged the belief that complex cognitive processes are uniquely human. At the forefront of these challenges has been research on mental time travel and future planning in jays. We tested whether Canada jays (*Perisoreus canadensis*) demonstrated future planning, using a procedure that has produced evidence of future planning in California scrub-jays. Future planning in this procedure is caching in locations where the bird will predictably experience a lack of food in the future. Canada jays showed no evidence of future planning in this sense and instead cached in the location where food was usually available, opposite to the behaviour described for California scrub-jays. We provide potential explanations for these differing results adding to the recent debates about the role of complex cognition in corvid caching strategies.

<https://royalsocietypublishing.org/doi/full/10.1098/rsbl.2021.0504>

Current Biology

PAPERS

HARIKRISHNAN RAJENDRAN et al – Ants resort to majority concession to reach democratic consensus in the presence of a persistent minority

Social groups often need to overcome differences in individual interests and knowledge to reach consensus decisions. Here, we combine experiments and modeling to study conflict resolution in emigrating ant colonies during binary nest selection. We find that cohesive emigration, without fragmentation, is achieved only by intermediate-sized colonies. We then impose a conflict regarding the desired emigration target between colony subgroups. This is achieved using an automated selective gate system that manipulates the information accessible to each ant. Under this conflict, we find that individuals concede their potential benefit to promote social consensus. In particular, colonies resolve the conflict imposed by a persistent minority through “majority concession,” wherein a majority of ants that hold first-hand knowledge regarding the superior quality nest choose to reside in the inferior one. This outcome is unlikely in social groups of selfish individuals and emphasizes the importance of group cohesion in eusocial societies.

[https://www.cell.com/current-biology/fulltext/S0960-9822\(21\)01689-4](https://www.cell.com/current-biology/fulltext/S0960-9822(21)01689-4)

Frontiers in Neuroscience

PAPERS

HATICE ZORA & VALÉRIA CSÉPE – Perception of Prosodic Modulations of Linguistic and Paralinguistic Origin: Evidence From Early Auditory Event-Related Potentials

How listeners handle prosodic cues of linguistic and paralinguistic origin is a central question for spoken communication. In the present EEG study, we addressed this question by examining neural responses to variations in pitch accent (linguistic) and affective (paralinguistic) prosody in Swedish words, using a passive auditory oddball paradigm. The results indicated that changes in pitch accent and affective prosody elicited mismatch negativity (MMN) responses at around 200 ms, confirming the brain’s pre-attentive response to any prosodic modulation. The MMN amplitude was, however, statistically larger to the deviation in affective prosody in comparison to the deviation in pitch accent and affective prosody combined, which is in line with previous research indicating not only a larger MMN response to affective prosody in comparison to neutral prosody but also a smaller MMN response to multidimensional deviants than unidimensional ones. The results, further, showed a significant P3a response to the affective prosody change in comparison to the pitch accent change at around 300 ms, in accordance with previous findings showing an enhanced positive response to emotional stimuli. The present findings provide evidence for distinct neural processing of different prosodic cues, and statistically confirm the intrinsic perceptual and motivational salience of paralinguistic information in spoken communication.

<https://www.frontiersin.org/articles/10.3389/fnins.2021.797487/full>

Journal of Linguistics

PAPERS

IVAN A. SAG et al with GEOFFREY K. PULLUM & THOMAS WASOW – Lessons from the English auxiliary system *Published online by Cambridge University Press: 03 January 2019*

The English auxiliary system exhibits many lexical exceptions and subregularities, and considerable dialectal variation, all of which are frequently omitted from generative analyses and discussions. This paper presents a detailed, movement-free account of the English Auxiliary System within Sign-Based Construction Grammar (Sag 2010, Michaelis 2011, Boas & Sag 2012) that utilizes techniques of lexicalist and construction-based analysis. The resulting conception of linguistic knowledge involves constraints that license hierarchical structures directly (as in context-free grammar), rather than by appeal to mappings over such structures. This allows English auxiliaries to be modeled as a class of verbs whose behavior is governed

by general and class-specific constraints. Central to this account is a novel use of the feature AUX, which is set both constructionally and lexically, allowing for a complex interplay between various grammatical constraints that captures a wide range of exceptional patterns, most notably the vexing distribution of unstressed do, and the fact that Ellipsis can interact with other aspects of the analysis to produce the feeding and blocking relations that are needed to generate the complex facts of EAS. The present approach, superior both descriptively and theoretically to existing transformational approaches, also serves to undermine views of the biology of language and acquisition such as Berwick et al. (2011), which are centered on mappings that manipulate hierarchical phrase structures in a structure-dependent fashion.

<https://www.cambridge.org/core/journals/journal-of-linguistics/article/lessons-from-the-english-auxiliary-system/6679B1EE13828805781AB9BE52F49741>

Mind & Language

PAPERS

LAURA GOW – Beyond adverbialism: A new non-relational theory of perceptual experience

All non-relational views of perceptual experience face Jackson's famous many-property problem. I argue that the original problem, and the existing responses to it, have focused too closely on the controversial terminology for which adverbialism is best known. We can also direct Jackson's many-property problem explicitly onto the adverbialist's metaphysics, generating a new challenge. The responses contemporary adverbialists and non-relationalists have made to the original objection are not successful against this challenge. We need a new non-relational account. I sketch an outline of a new theory, and motivate the view by explaining how it can respond successfully to this additional challenge.

<https://onlinelibrary.wiley.com/doi/abs/10.1111/mila.12396>

Nature

PAPERS

GREGG A. CASTELLUCCI et al – A speech planning network for interactive language use

During conversation, people take turns speaking by rapidly responding to their partners while simultaneously avoiding interruption. Such interactions display a remarkable degree of coordination, as gaps between turns are typically about 200 milliseconds—approximately the duration of an eyeblink. These latencies are considerably shorter than those observed in simple word-production tasks, which indicates that speakers often plan their responses while listening to their partners. Although a distributed network of brain regions has been implicated in speech planning, the neural dynamics underlying the specific preparatory processes that enable rapid turn-taking are poorly understood. Here we use intracranial electrocorticography to precisely measure neural activity as participants perform interactive tasks, and we observe a functionally and anatomically distinct class of planning-related cortical dynamics. We localize these responses to a frontotemporal circuit centred on the language-critical caudal inferior frontal cortex (Broca's region) and the caudal middle frontal gyrus—a region not normally implicated in speech planning. Using a series of motor tasks, we then show that this planning network is more active when preparing speech as opposed to non-linguistic actions. Finally, we delineate planning-related circuitry during natural conversation that is nearly identical to the network mapped with our interactive tasks, and we find this circuit to be most active before participant speech during unconstrained turn-taking. Therefore, we have identified a speech planning network that is central to natural language generation during social interaction.

<https://www.nature.com/articles/s41586-021-04270-z>

Nature Human Behaviour

PAPERS

QI SU, ALEX MCAVOY, YOICHIRO MORI & JOSHUA B. PLOTKIN – Evolution of prosocial behaviours in multilayer populations

Human societies include diverse social relationships. Friends, family, business colleagues and online contacts can all contribute to one's social life. Individuals may behave differently in different domains, but success in one domain may engender success in another. Here, we study this problem using multilayer networks to model multiple domains of social interactions, in which individuals experience different environments and may express different behaviours. We provide a mathematical analysis and find that coupling between layers tends to promote prosocial behaviour. Even if prosociality is disfavoured in each layer alone, multilayer coupling can promote its proliferation in all layers simultaneously. We apply this analysis to six real-world multilayer networks, ranging from the socio-emotional and professional relationships in a Zambian community, to the online and offline relationships within an academic university. We discuss the implications of our results, which suggest that small modifications to interactions in one domain may catalyse prosociality in a different domain.

<https://www.nature.com/articles/s41562-021-01241-2>

Nature Scientific Reports

PAPERS

D. B. KRUPP & WES MACIEJEWSKI – The evolution of extraordinary self-sacrifice

From a theoretical perspective, individuals are expected to sacrifice their welfare only when the benefits outweigh the costs. In nature, however, the costs of altruism and spite can be extreme, as in cases of irreversible sterility and self-destructive

weaponry. Here we show that “extraordinary” self-sacrifice—in which actors pay costs that exceed the benefits they give or the costs they impose on recipients—can evolve in structured populations, where social actions bring secondary benefits to neighboring kin. When given information about dispersal, sedentary actors evolve extraordinary altruism towards dispersing kin. Likewise, when given information about dispersal and kinship, sedentary actors evolve extraordinary spite towards sedentary nonkin. Our results can thus be summed up by a simple rule: extraordinary self-sacrifice evolves when the actor’s neighbors are close kin and the recipient’s neighbors are not.

<https://www.nature.com/articles/s41598-021-04192-w>

PLoS One

PAPERS

SHAN WANG, RUHAN LIU & CHU-REN HUANG – Social changes through the lens of language: A big data study of Chinese modal verbs

Leech’s corpus-based comparison of English modal verbs from 1961 to 1992 showed the steep decline of all modal verbs together, which he ascribed to continuing changes towards a more equal and less authority-driven society. This study inspired many diachronic and synchronic studies, mostly on English modal verbs and largely assuming the correlation between the use of modal verbs and power relations. Yet, there are continuing debates on sampling design and the choices of corpora. In addition, this hypothesis has not been attested in any other language with comparable corpus size or examined with longitudinal studies. This study tracks the use of Chinese modal verbs from 1901 to 2009, covering the historical events of the New Culture Movement, the establishment of the PRC, the implementation of simplified characters and the completion and finalization of simplification of the Chinese writing system. We found that the usage of modal verbs did rise and fall during the last century, and for more complex reasons. We also demonstrated that our longitudinal end-to-end approach produces convincing analysis on English modal verbs that reconciles conflicting results in the literature adopting Leech’s point-to-point approach.

<https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0260210>

PNAS

PAPERS

PATRICIA KANNGIESSER et al with MICHAEL TOMASELLO – Children across societies enforce conventional norms but in culturally variable ways

Individuals in all societies conform to their cultural group’s conventional norms, from how to dress on certain occasions to how to play certain games. It is an open question, however, whether individuals in all societies actively enforce the group’s conventional norms when others break them. We investigated third-party enforcement of conventional norms in 5- to 8-year-old children (n = 376) from eight diverse small-scale and large-scale societies. Children learned the rules for playing a new sorting game and then, observed a peer who was apparently breaking them. Across societies, observer children intervened frequently to correct their misguided peer (i.e., more frequently than when the peer was following the rules). However, both the magnitude and the style of interventions varied across societies. Detailed analyses of children’s interactions revealed societal differences in children’s verbal protest styles as well as in their use of actions, gestures, and nonverbal expressions to intervene. Observers’ interventions predicted whether their peer adopted the observer’s sorting rule. Enforcement of conventional norms appears to be an early emerging human universal that comes to be expressed in culturally variable ways.

<https://www.pnas.org/content/119/1/e2112521118.abstract>

QI SU, BENJAMIN ALLEN & JOSHUA B. PLOTKIN – Evolution of cooperation with asymmetric social interactions

How cooperation emerges in human societies is both an evolutionary enigma and a practical problem with tangible implications for societal health. Population structure has long been recognized as a catalyst for cooperation because local interactions facilitate reciprocity. Analysis of population structure typically assumes bidirectional social interactions. But human social interactions are often unidirectional—where one individual has the opportunity to contribute altruistically to another, but not conversely—as the result of organizational hierarchies, social stratification, popularity effects, and endogenous mechanisms of network growth. Here we expand the theory of cooperation in structured populations to account for both uni- and bidirectional social interactions. Even though unidirectional interactions remove the opportunity for reciprocity, we find that cooperation can nonetheless be favored in directed social networks and that cooperation is provably maximized for networks with an intermediate proportion of unidirectional interactions, as observed in many empirical settings. We also identify two simple structural motifs that allow efficient modification of interaction directions to promote cooperation by orders of magnitude. We discuss how our results relate to the concepts of generalized and indirect reciprocity.

<https://www.pnas.org/content/119/1/e2113468118.abstract>

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