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Understanding hunter-gatherer cultural evolution needs network thinking

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Abstract: Hunter-gatherers past and present live in complex societies, and the structure of these can be assessed using social networks. We outline how the integration of new evidence from cultural evolution experiments, computer simulations, ethnography and archaeology open new research horizons to understand the role of social networks in cultural evolution.

44 **Keywords:** Hunter-gatherers, Social Networks, Cultural Evolution, Archaeology,
45 Evolutionary Anthropology.

46

47 **Cultural evolution: it's time for thinking about social networks**

48

49 Social networks, referred here as a structure in which individuals and groups of
50 individuals are connected to each other through social ties, play a central but not yet well-
51 understood role in human cultural evolution. Here, we advocate for the adoption of a
52 **'network thinking'** (see Glossary) perspective in cultural evolutionary research, when
53 dealing with past and present hunter-gatherers populations. This approach necessarily
54 requires (i) recognizing that social learning processes involved the transmission of
55 information throughout different levels of social interaction: among individuals from the
56 same residential group and between members of different residential groups. Therefore,
57 this information flow is embedded in large and complex social networks; (ii)
58 understanding that population size scales up the complexity of these social networks,
59 from interactions among few individuals to direct and indirect interactions among
60 hundreds of individuals in much larger metapopulations; and (iii) investigating the
61 relationship between past social network dynamics and cultural change using
62 archaeological datasets.

63 We argue the adoption of 'network thinking' in cultural evolution can only be
64 adequately explored through a multidisciplinary combination of data, methodologies
65 and theoretical frameworks from archaeology, evolutionary anthropology, psychology,
66 and network science. Specifically, this includes the evidence available from the
67 archaeological record, ethnographic studies, computer simulations and cultural
68 evolution experiments on one side and the theoretical perspectives developed in cultural
69 evolutionary and complex systems theories on the other. Here, we show how recent
70 research has shifted the conceptual background of social connectivity in hunter-
71 gatherer's cultural evolution and discuss three major areas for prospective research: (i)
72 the application of social network analysis to the archaeological record; (ii) the
73 introduction of conceptual frameworks from network theory (Fig.1) and (iii) the
74 interdependence between social networks and cultural evolution.

75

76

Figure 1

77

78 **New perspectives on the role of social connectivity in hunter-gatherers cultural**
79 **transmission**

80

81 The core principle of cultural evolutionary theory is that individuals learn through a
82 combination of individual and social learning. Under certain conditions, these learning
83 strategies can create cumulative culture which is recognized by the presence of traits that
84 could not be invented by a single individual, and that are gradually improved over time
85 due to the inheritance of knowledge and know-how from previous generations. We view
86 social networks as a central but still understudied component of cultural evolution
87 because, by definition, cultural transmission is information flow and retention through
88 structured populations at multiple scales.

89 Recent research has applied social network analysis to explore the influence of social
90 connectivity on cultural evolution using lab experiments, computer simulations and
91 ethnographic data [1-3]. Cultural evolution experiments in which participants can learn
92 from each other to develop complex artifacts have demonstrated that populations
93 subdivided into partially isolated subgroups produce more diverse cultural traits than
94 fully connected populations and reach higher levels of cultural complexity when
95 innovation depends on cultural diversity [1]. Computational modeling has investigated
96 the effect of different human mobility strategies on information transmission through
97 social networks and found that central-place foraging, in which hunter-gatherers forage
98 and bring food back to the campsite, improve the dissemination of social information in
99 large populations [2].

100 Complementing these approaches, studies simulating cultural evolution over real
101 networks from extant hunter-gatherer communities have shown that social structures
102 characterised by multiple levels of clustering of households within camps and camps
103 within meta-populations can accelerate cultural evolution [3]. Furthermore, features
104 such as co-residence, cooperation with unrelated individuals, multilocality, fluid
105 sociality and high between-camp mobility might have had a major influence on the
106 cognitive mechanisms (e.g., high-fidelity transmission, innovation, teaching, and
107 combinatorial innovation) underlying **cumulative cultural evolution**. This research has
108 significantly contributed to replacing the long-held view of hunter-gatherers living in
109 small-scale societies by a new perspective which highlights how small co-residence
110 groups are dynamically connected to much larger populations forming expansive

111 networks of social interaction at large spatial scales [3-4]. In spite of contributing to a
112 paradigm shift, experimental and ethnographic studies do not have the time depth to
113 reveal how these changes might have impacted cultural evolution across generations.
114 Archaeological data can step in here.

115

116 **Applying social network analysis to the archaeological record**

117

118 The archaeological record left by past hunter-gatherers provides long-term perspectives
119 on the relationship between patterns of social interaction and cultural evolution. From
120 the Upper Palaeolithic onwards, archaeological evidence is often sufficiently
121 representative to build spatio-temporal networks at regional scales. Studies applying
122 formal social network analysis to the hunter-gatherer archaeological record have focused
123 on a range of issues including processes of cultural diversification, reconstructing
124 network topologies, and the growth of settlement interconnectedness and its decline in
125 relation to environmental hazards [5,6 and references in there].

126 The application of social network analysis to archaeological datasets faces many
127 challenges including the low chronological resolution of the Paleolithic record –with
128 time scales of centuries and millennia– research and **taphonomic biases**. These
129 limitations are highly germane to the selection of appropriate classes of material culture
130 to reconstruct archaeological networks, as well as in the selection of different statistical
131 and modeling methods to evaluate their representativeness and robustness. Additional
132 constraints come from the process of network construction itself, particularly when
133 aggregating data over broader periods or when dividing the archaeological record into
134 shorter subperiods for determining the spatial and temporal dynamics of those networks.
135 A set of recent developments in evolutionary archaeology – in particular, new forms of
136 quantitative archaeological systematics as well as chronological and spatial modelling –
137 open new prospects for finer-grained applications of social network analysis to cultural
138 evolutionary processes. First, the re-evaluation of **cultural taxonomy** using cultural
139 evolutionary theory-driven approaches seeks to capture population and network
140 structure through artefact proxies [7]. Second, recent advances in **radiocarbon**
141 **chronological modeling** have yielded new insights into the reconstruction of long-term
142 changes in population size and spatio-temporal settlement dynamics at regional scales
143 [8]. Third, coupled geographic information systems and **agent-based modeling** allows
144 a more realistic appreciation of the role of geographic barriers and environmental

145 constraints play in the formation of social networks in the archaeological record [9].
146 Importantly, the publication of archaeological datasets and methods accessible through
147 on-line data infrastructures facilitates new data science approaches and reproducibility.

148 

149 In sum, the application of **social network analysis** to the hunter-gatherer archaeological
150 record opens vistas onto *long durée* cultural evolutionary processes from a population
151 perspective, such as the spread of new behaviors or technologies by social diffusion
152 mechanisms, the diversification or decimation of culture, and the relationship between
153 cultural changes with socio-spatial structures, climatic and environmental changes, and
154 population dynamics.

155

156

157 **Hunter-gatherer social networks and cultural evolution interdependence**

158

159 Studying the influence of social connectivity on cultural evolution is central, but it is
160 only one side of the phenomenon we are interested in. We also need to better
161 understand how cultural transmission might in turn condition the dynamics of social
162 networks.

163 Indeed, recent research suggests the presence of feedback between network dynamics
164 and cultural transmission and highlights the long-term role such feedbacks may play in
165 long-term cultural evolution [1, 10]. For instance, technological innovations may affect
166 connectivity patterns through population increase or enhanced mobility, while social
167 transmission rates or cultural trait stability might be conditioned by social structure.

168 This interplay between network dynamics and cultural transmission is complex and
169 likely to operate across multiple scales and with interactions of multiple factors (e.g.,
170 biogeography, environmental dynamics and demography) that have not yet been fully
171 explored in evolutionary archaeology [11]. Experimental and ethnographic studies can
172 contribute to fill this gap, as they provide insight on culture-mediated mechanisms
173 underlying social network change. Future work may profitably focus on integrating
174 these complementary approaches, as well as their articulation with archaeological data
175 of different granularity.

176 For decades, network scientists have developed a growing body of methods and
177 concepts to explore dynamics of networks and their interplay with information

178 transmission [12]. We can now use this knowledge to test evolutionary models of the
179 interdependence of social structure and cultural change in hunter-gatherer societies.

180

181 **A call for ‘network thinking’**

182

183 Our call for ‘network thinking’ in hunter-gatherer cultural evolution is based on
184 growing evidence for the relationship between social connectivity and cultural change
185 provided by recent ethnographic, computational and experimental studies. While
186 research is beginning to show how hunter-gatherer sociality shapes cumulative culture
187 today, the investigation of social structures in the past is required to fully understand
188 cultural evolution. By using archaeological data to infer and analyze past social
189 networks, we can offer unprecedented insights into how longitudinal changes in social
190 connectivity interacted with human cultural evolution, both in terms of undergirding the
191 remarkable accumulation of species-wide culture as well as the occasional shocks
192 leading to demographic and cultural decline and extirpation. Network science naturally
193 links interactions among individuals with emergent collective macrophenomena and so
194 can be used to effectively integrate all these complementary perspectives. We believe
195 that this cross-disciplinary application of network thinking will improve our
196 understanding of the long-term interplay between human social structure and cultural
197 change.

198

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207

208

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248 **Captions list**

249

250 Figure 1. A) Crossing disciplinary boundaries to apply ‘network thinking’ in hunter-
251 gatherer cultural evolution. Computational simulations including Agent Based Modeling
252 (ABM), cultural evolution experiments and ethnographic studies provide evidence for the
253 effect of social connectivity on cultural evolution. While laboratory studies offer insights
254 into small-scale mechanisms operating between individuals, ethnographic studies allow
255 the observation of social networks ‘in the wild’- Yet, these approaches alone cannot reveal
256 how networks change over long period of time and how this impacts cultural evolutionary
257 trajectories across generations and in relation to extrinsic factors such as between-group
258 contact or climate change. Archaeological data fill this gap. B) Scaling effects of
259 population size in hunter-gatherer social networks: populations are structured in nested
260 levels of social organization (families or households, bands, regional bands,
261 subpopulations and metapopulations). The analysis of world-wide ethnographic datasets
262 recurrently finds this nested self-similar structure characteristic of small-world,
263 hierarchically modular networks. The information flow leads to the emergence of small-
264 world networks where highly clustered local interactions are embedded within much
265 larger, but sparsely connected multilevel metapopulations forming decentralized
266 knowledge systems [4]. Depicted networks have been produced by a network model
267 combining constraints on module size at each hierarchical level and random wiring of
268 links among families/nodes.

269

270 Figure 2. Network dynamics and archaeological social networks. The left panel depicts
271 different kind of material culture proxies of social interaction: Pierced shells, used as
272 personal ornaments, reflect broad social interactions in which long-distance circulation
273 of materials are embedded, whereas lithic projectile points and harpoons are considered
274 utilitarian objects, whose formal and technological traits were transmitted in social
275 learning contexts. The central panel represents the reconstruction of social networks using
276 archaeological data sets. The right panel shows a theoretical social network changing
277 through three time slices (t_1 , t_2 and t_3), and potential consequences of such dynamics in
278 terms of cultural evolutionary processes. At t_1 we find the complete social network,
279 formed by interconnected regional bands within a subpopulation. At that moment, the
280 density and strength of connections favor processes of social diffusion of technologies
281 (a); at t_2 , the social network presents fewer nodes than at t_1 , and the strength among the
282 connections is higher within each regional band than at subpopulation level. This socio-
283 spatial structural configuration privileges intra-regional band information exchange, and
284 inter-regional differentiation which can result in cultural diversification (b). Finally, at t_3 ,
285 the network is significantly smaller, fragmented and connections are weak both within
286 and across regional bands. This state increases the chances of cultural drift (c), a process
287 by which random copying errors in smaller and/or less connected populations can lead to
288 the disappearance of existing cultural variants.

289

290