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Co-evolution of behavior and social network structure promotes human cooperation

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Introduction

Human cooperative behavior is still in many aspects an evolutionary puzzle since defectors often benefit from cooperative interactions without bearing the associated costs. Theoretical work has shown that network structure can promote the evolution of cooperation. Lately theoretical research has focused on dynamic social networks, which are predicted to enhance cooperation further than static network structures. We present an experimental study[1] where humans played iterated prisoner's dilemmas with multiple partners simultaneously in either a static or a dynamic social network. The dynamic network is created by the active-linking mechanism of Pacheco and colleagues[2-4].

Method

- Two treatments (anonymous conditions)
  - *Static network* (played prisoner's dilemma only)
  - *Dynamic network* (prisoner's dilemma followed by a link-breaking stage)
- 10 groups per treatment of 10 individuals (♀=55, ♂=45)
- Starting network structure (Fig. 1A)
- Duration of game unknown (30 rounds)
- For each partner, participants decided whether to cooperate (C) or defect (D) (cf. payoff matrix)
- Dynamic network groups: players can end their relationships & receive new partners, randomly chosen (cf. Fig. 1B)

		partner C	*partner* D
focus player	C	0.25 €	-0.10 €
	D	0.40 €	0.00 €

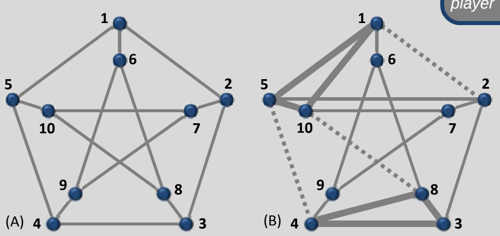

Fig. 1 ***Social network topology***. Circles represent individuals and lines are links between individuals. *(A)* Initial network topology. *(B)* Example of link breaking (dotted lines: former links; bold lines forming a triangle: cluster).

Results

Cooperation:

- Cooperation levels were significantly higher in dynamic networks (which are much more natural settings for human societies) compared to static networks (Fig. 2).

Social links in dynamic networks:

- Links to defective partners were more likely to be cut; whereas two cooperative participants built up long-term relationships (Fig. 3).

Clustering within the dynamic networks:

- Much more clustering (cf. Fig. 1B) occurred than would be expected under random link-breaking decisions.
- The more cooperative players were the more they were clustered, i.e. their cooperative friends are also friends with each other.

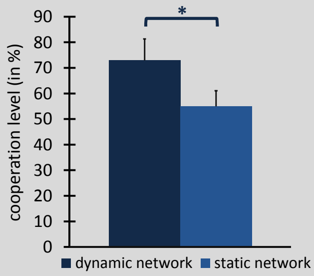

Fig. 2 ***Average cooperation level*** (+ SD) of treatments.

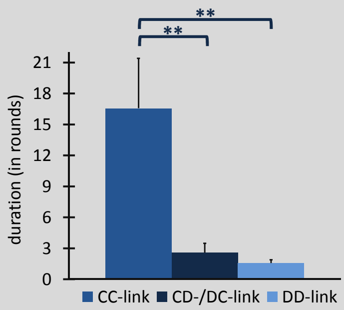

Fig. 3 ***Duration of links*** (+ SD). Participants cooperated, C, or defected, D. Hence, they formed CC-links, CD-links (DC-links, respectively), or DD-links.

Main Conclusions

- Our findings are in line with theoretical assumptions for the evolution of cooperation in structured populations.
  → In the dynamic networks participants had the opportunity to break existing social links. This and the associated self-organizing processes lead to higher cooperation.
- Assortment of cooperative participants into clusters generates a social environment that can protect them from exploitation.
- Surprisingly, participants sorted into clusters without any information on the network topology.
  → Clustering (global level) emerged through self-organization from local interactions (prisoner's dilemma and linking decisions).
- Participants' linking decisions are influenced by the prisoner's dilemma outcome, leading to changes in the dynamic network.
- Changes of the network structure (e.g. cluster formation) feed back on how participants choose their behaviors.
  → Generating a feedback loop between local dyadic interactions & the global network level, i.e. the ecological context of players.

⇒ This highlights the importance of the interaction between the ecological context and selective pressures on cooperation.

1 Fehl, K, van der Post, DJ & Semmann, D (2011). Co-evolution of behavior and social network structure promotes human cooperation. *Ecol. Lett.*, *14*, 546–551.
2 Pacheco, JM, Traulsen, A & Nowak, MA (2006a). Active linking in evolutionary games. *J. Theor. Biol.*, *243*, 437-443.
3 Pacheco, JM, Traulsen, A & Nowak, MA (2006b). Coevolution of strategy and structure in complex networks with dynamical linking. *Phys. Rev. Lett.*, *97*, 258103.
4 Pacheco, JM, Traulsen, A, Ohtsuki, H & Nowak, MA (2008). Repeated games and direct reciprocity under active linking. *J. Theor. Biol.*, *250*, 723-731.

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