
# How phase transitions trigger the emergence of Collective Intelligence in human groups? An experimental investigation

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# Collective Intelligence

- **Ability** of human groups to perform well on a variety of tasks (Woolley et al. 2010)

- Literature focuses on **determinants** and processes leading to its emergence (Woolley et al., 2015; De Vincenzo et al. 2017; Massari, Giannoccaro, Carbone 2018)

- Decision-making models inspired by statistical physics are able to capture its emergence (Carbone, Giannoccaro 2005, De Vincenzo, Carbone, Giannoccaro 2017)

# The model of collective decision making

- ***M* interacting members** solve a combinatorial problem: finding the vector of choices on decisions, i.e. $d = (d_1, d_2, \ldots, d_N)$, with the highest fitness value $V$ on a complex landscape

- The state vector of the whole system results as $\boldsymbol{s} = (\boldsymbol{s}_1 \boldsymbol{s}_2, .., \boldsymbol{s}_N) = (\sigma_1^1, \sigma_2^1, .., \sigma_M^1, \ldots, \sigma_1^N, \sigma_2^N, .., \sigma_M^N)$

- The **Hamiltonian** of the system is defined as:

$$H(s) = -\frac{1}{2} J A I s \cdot s - \rho V(s) = -\frac{1}{2} J \sum_{ij} A_{ij} I_{ij} s_i s_j - \rho V(s)$$

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# The dynamics

$$\frac{dP(\mathbf{s},t)}{dt} = -\sum_l w(\mathbf{s}_l \to \mathbf{s}'_l) P(\mathbf{s}_l,t) + \sum_l w(\mathbf{s}'_l \to \mathbf{s}_l) P(\mathbf{s}'_l,t)$$

$$w(\mathbf{s}_l \to \mathbf{s}'_l) = \frac{1}{2}\left[1 - s_l \tanh\left(\frac{\beta J}{\langle\kappa\rangle}\sum_h A_{lh} I_{lh} s_h\right)\right] \times \exp\{\beta' [\Delta V(\mathbf{s}'_l, \mathbf{s}_l)]\}$$

- $\boldsymbol{\beta}$ is the inverse of social temperature
- $\boldsymbol{J}$ is the coupling constant of social interactions
- $\boldsymbol{A = A_{lh}}$ is a N-block adjacency matrix describing who interacts with whom
- $\boldsymbol{\beta'}$ is related to the degree of uncertainty associated with the knowledge of the fitness landscape (the higher $\beta'$, the less the uncertainty)
- $\boldsymbol{\Delta V(s'_l, s_l)}$ is the change in pay-off perceived by member $i$ when the opinion flips from $s'_l$ to $s_l$

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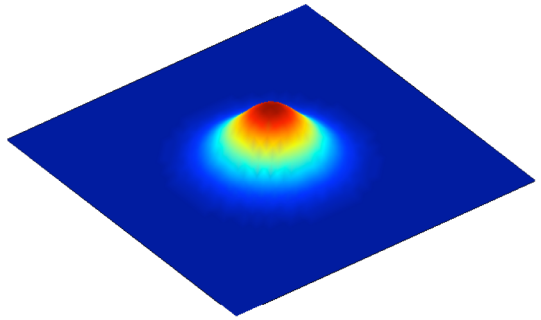
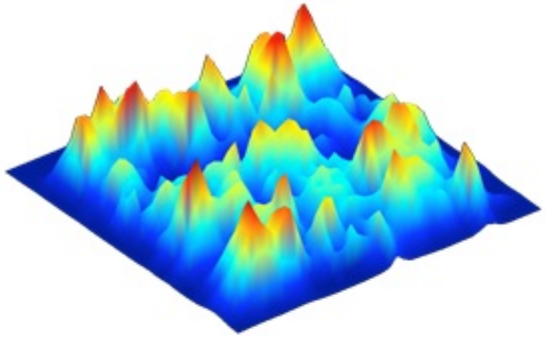
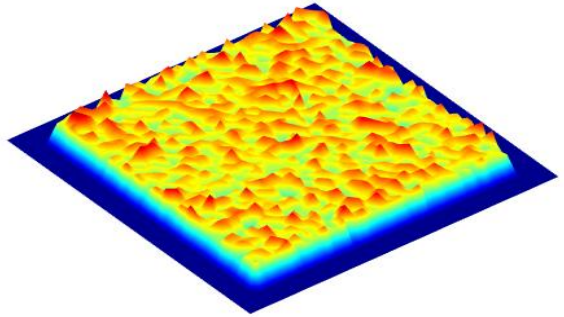
# Group Performance







## Features of a NK Kauffmann landscape:

- $N$ – Number of binary decisions
- $K$ – Number of interacting decisions
- $\boldsymbol{d}_{\mathbf{k}} = (d_1, d_2, \ldots d_N)$, the vector of decision values, made by *k-th* agent
- The pay-off function $V(\boldsymbol{d})$ associates a fitness value to each vector $\boldsymbol{d}$

## Group Performance:

$$V(\mathbf{d}) = \frac{1}{N}\sum_{j=1}^{N} W_j\left(d_j, d_1^j, d_2^j, .., d_K^j\right)$$

**FITNESS**

$$\langle C(t)\rangle = \frac{1}{M^2 N}\sum_{j=1}^{N}\sum_{kh=1}^{M}\left\langle \sigma_k^j(t)\,\sigma_h^j(t)\right\rangle$$

**CONSENSUS**

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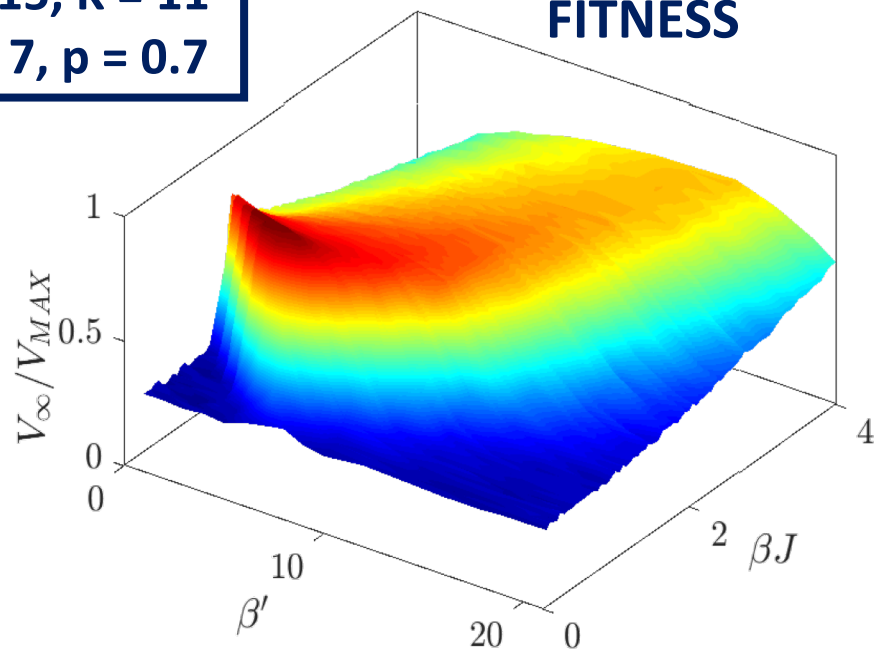
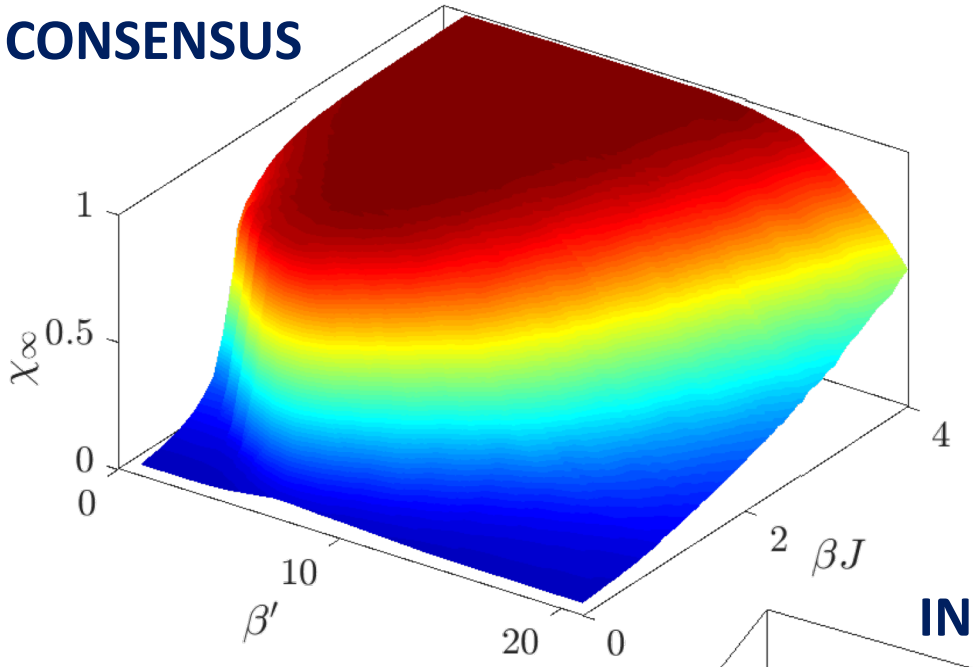
# The emergence of CI

**N = 15, K = 11**
**M = 7, p = 0.7**

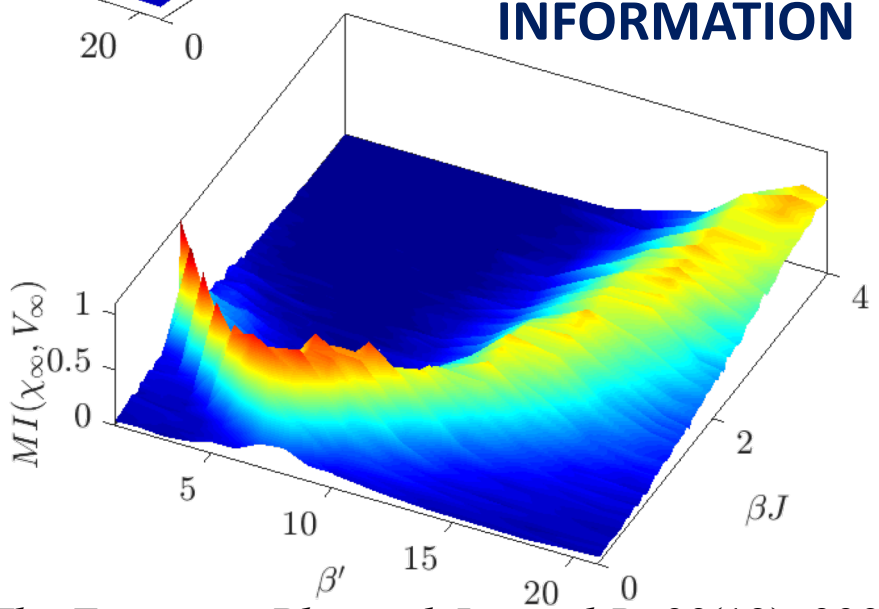
**FITNESS**




**CONSENSUS**




**MUTUAL INFORMATION**




- **Critical conditions** ($\beta$',$\beta J$) lead to a phase transition of the consensus value. A similar steep increase is observed on group fitness value

- The **collective intelligence region**, where the group achieves its highest fitness value, is located close the minimum point ($\beta'_{min}$, $\beta J_{min}$) of the U-shaped critical front

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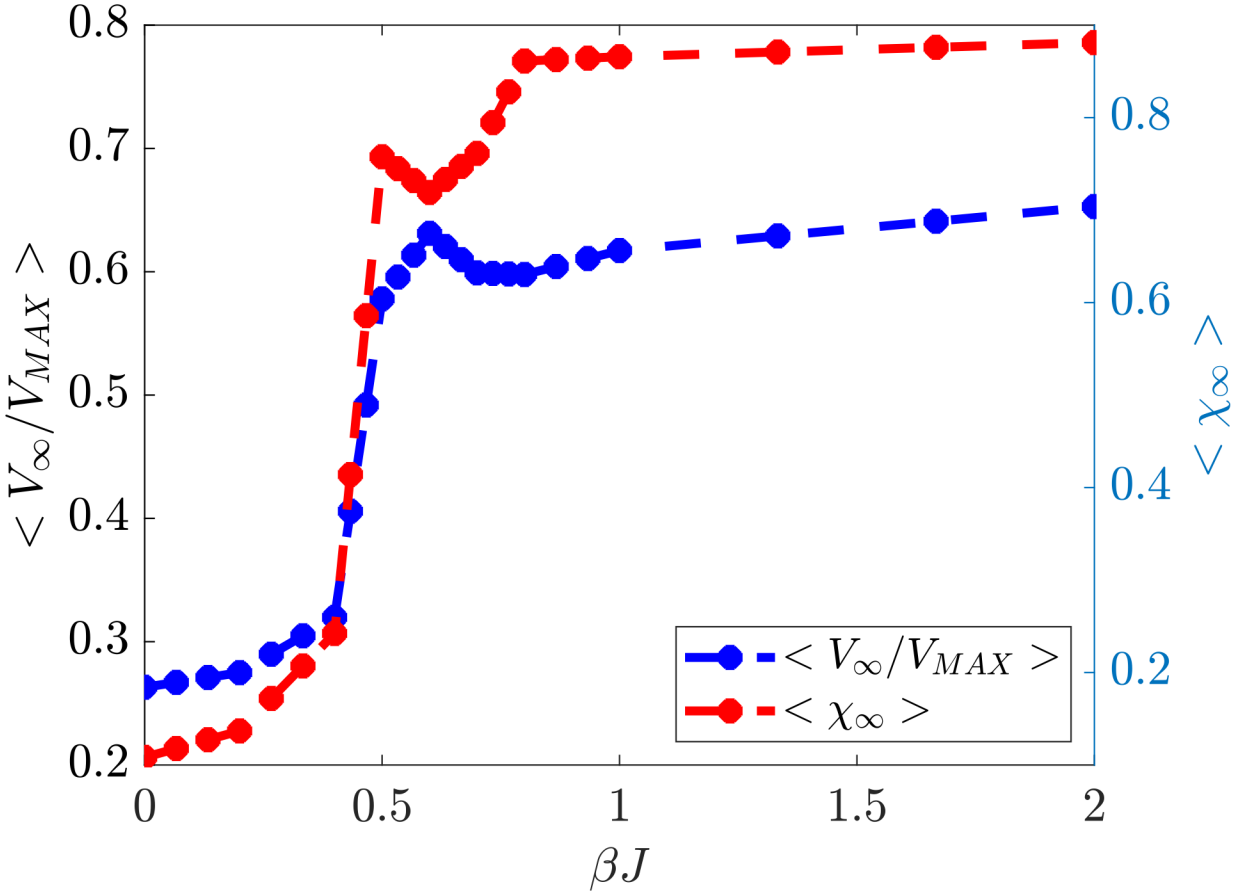
# The research aim

- To perform behavioural experiments of group decision-making that mimic the DMM

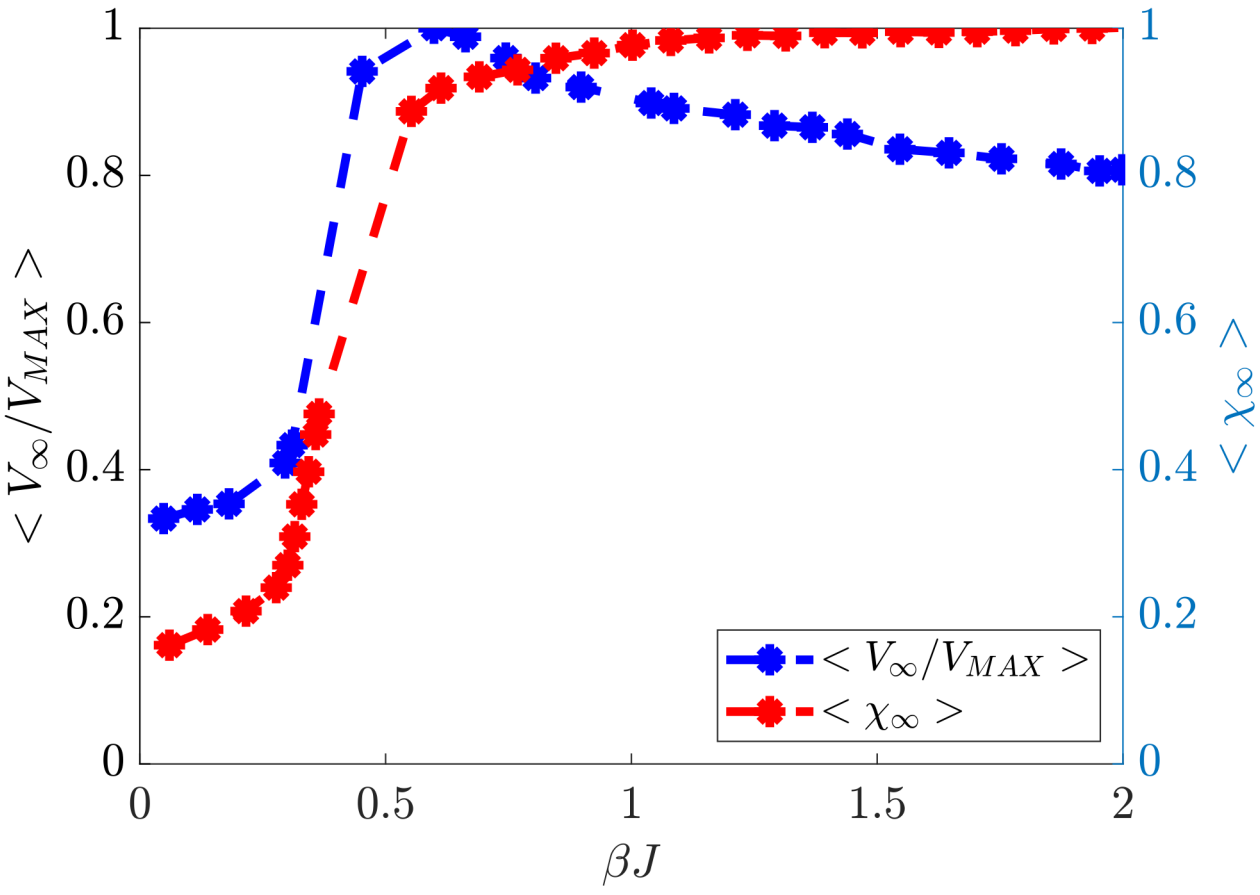
- To investigate whether and how the strength of social interaction influences the group performance

# The emergence of CI …

## EXPERIMENTS

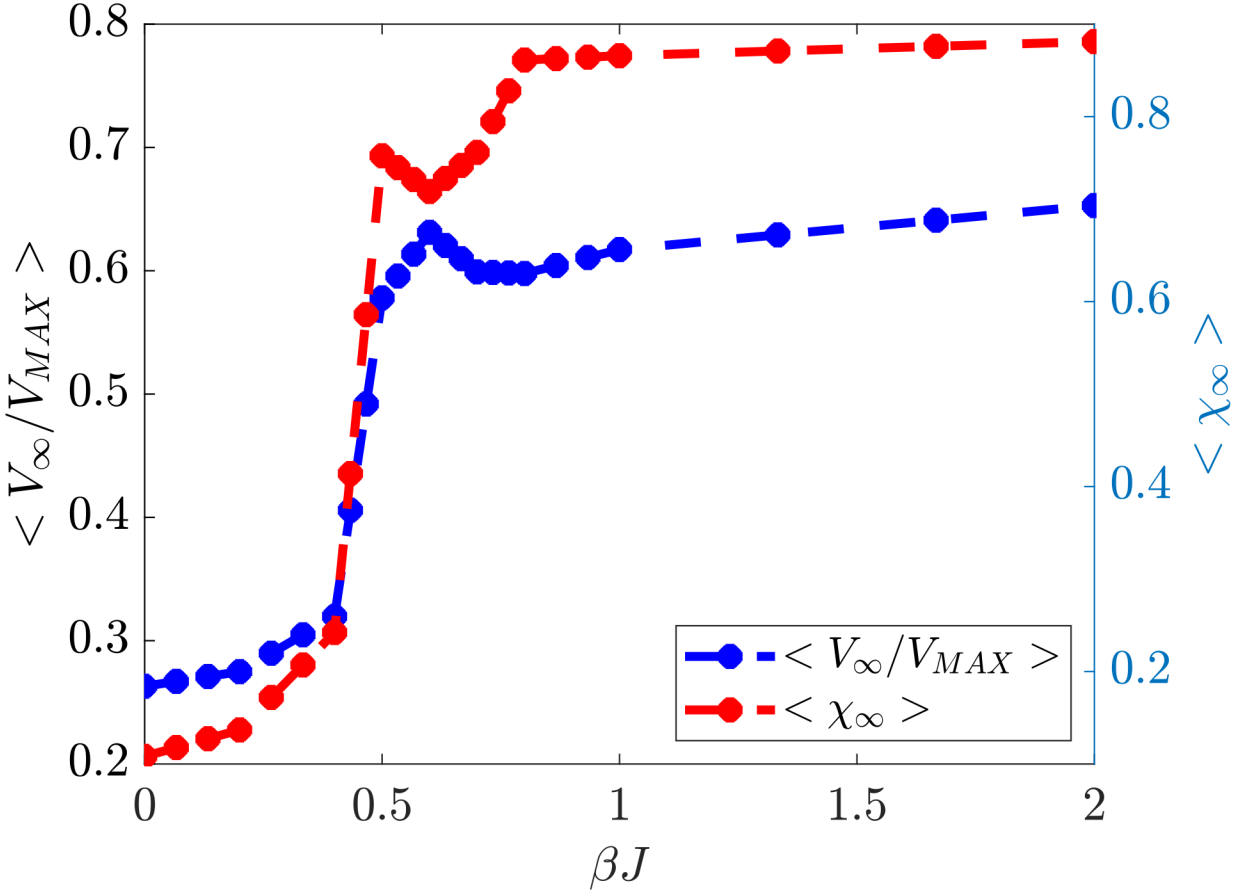


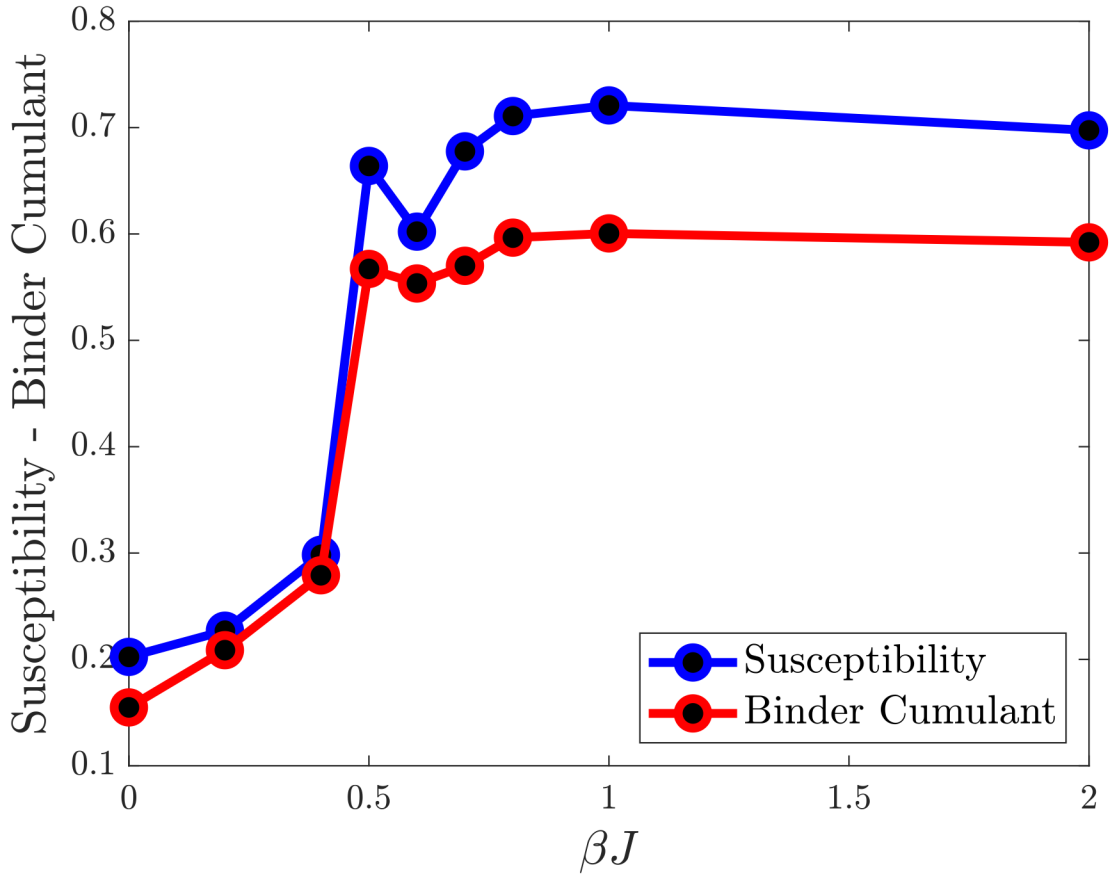

## MODEL



# … with signs of criticality

## EXPERIMENTS



# Conclusions

- We performed behavioural experiments of group decision-making on real human groups to investigate whether and how the strength of social interaction influences the group performance

- The strength of social interaction affects the group performance. At criticality, a phase transition from low to high values of the level of consensus and a similar steep increase in the group fitness occur

- Further investigations will be devoted to studying the phenomenon of *groupthink* that occurs in highly-interacting groups

# Collective Intelligence Research Group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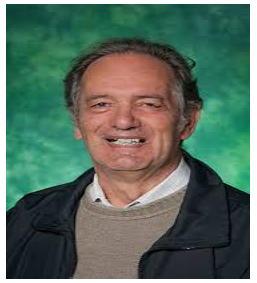


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**Thanks to all …**