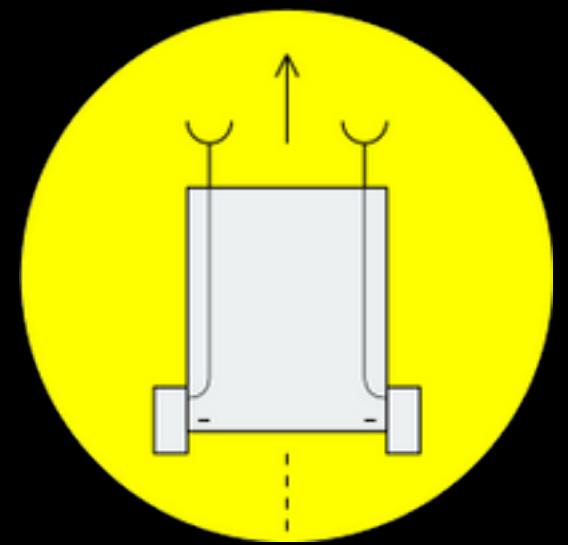


Group Intelligence in Social Robots

Filipa Correia

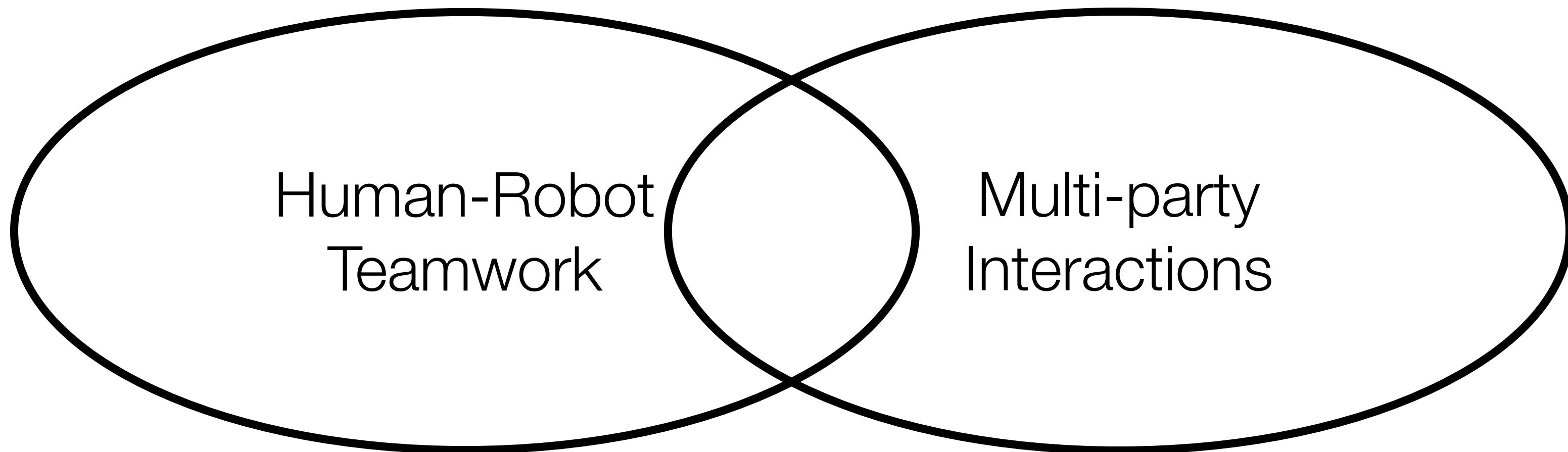


Talking Robotics - April 2nd 2021

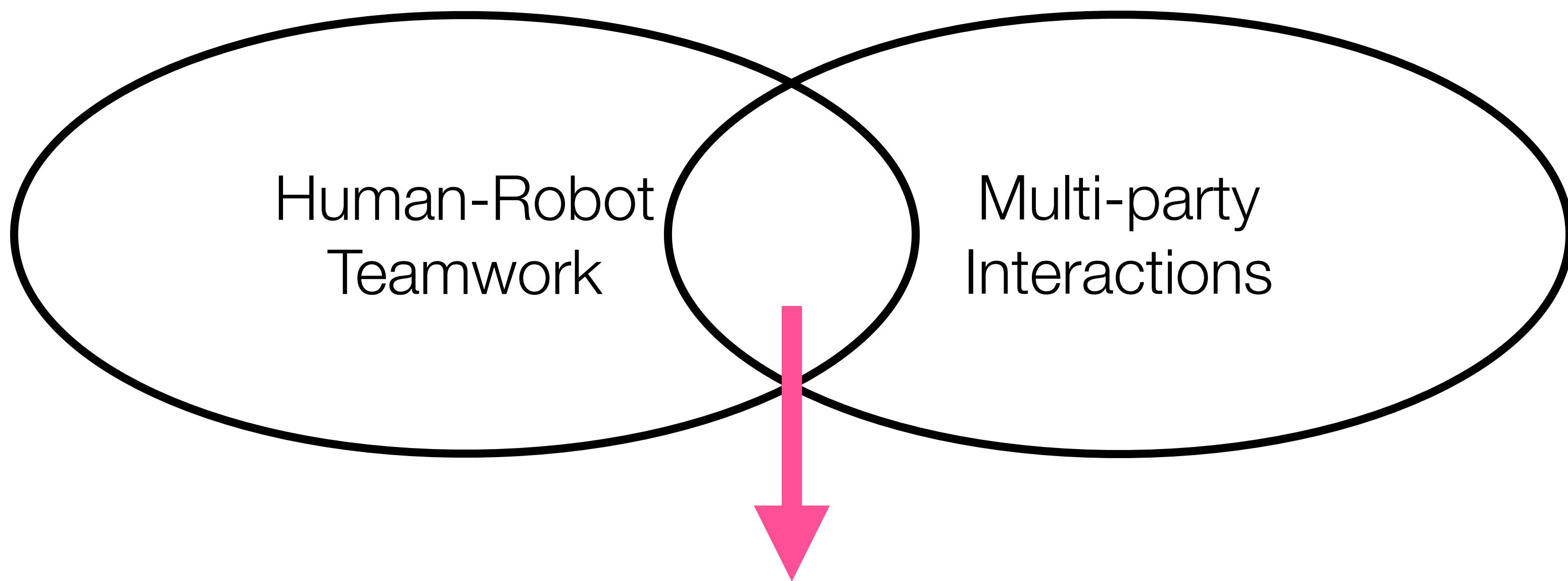


Motivation & Plan

Novelty



Novelty



What is a Group?

Group - “two or more individuals who are connected by and within social relationships”

- Interactions
- Goals
- Interdependence
- Structure
- Cohesion

What is a Team?

Team - “unified, cohesive group”

- Coordinated interactions
- Common goals
- Strong interdependence
- Structure
- Cohesion

What is a Team?

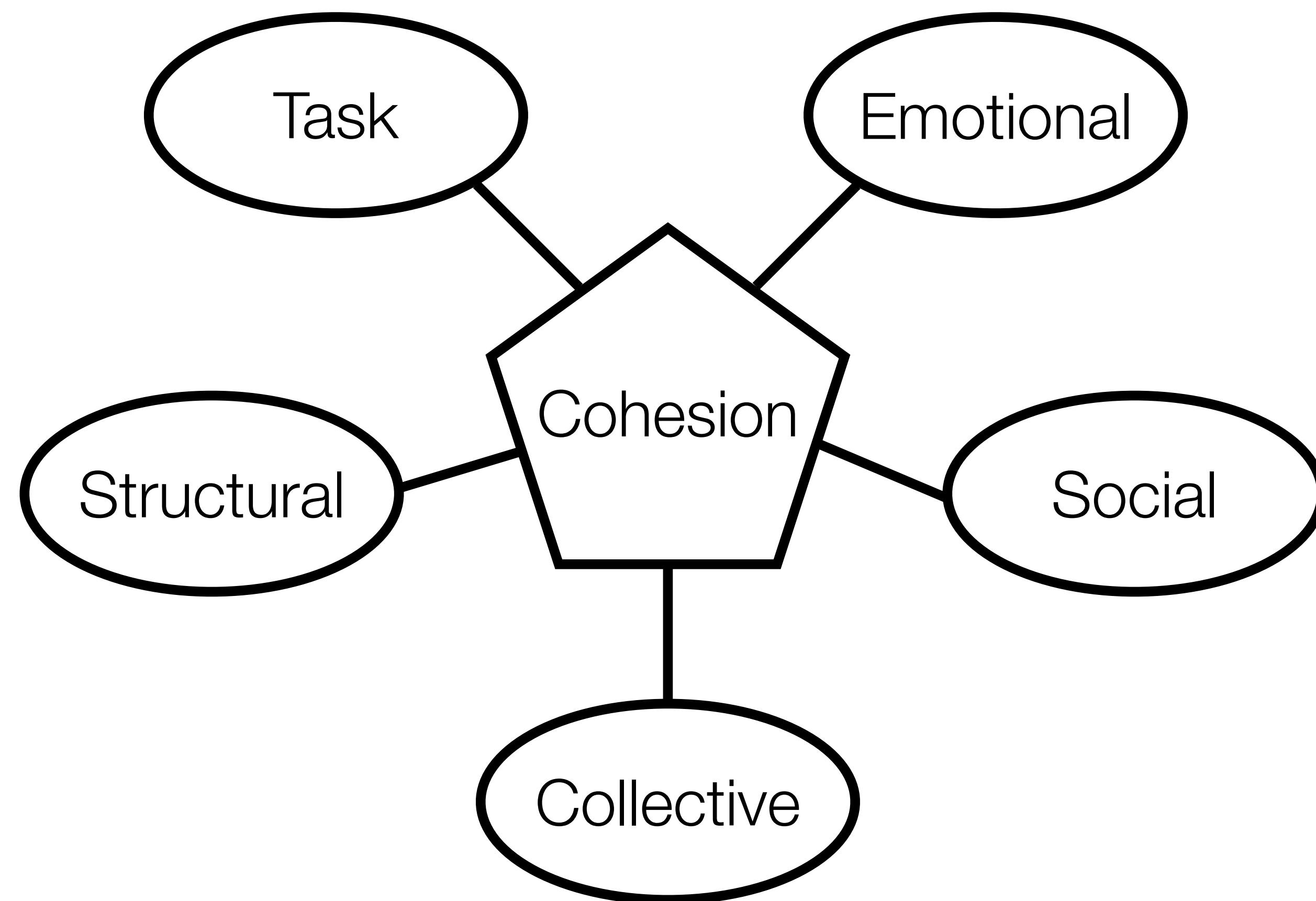
Team - “unified, cohesive group”

- Coordinated interactions
- Common goals
- Strong interdependence
- Structure
- **Cohesion**

Research Problem

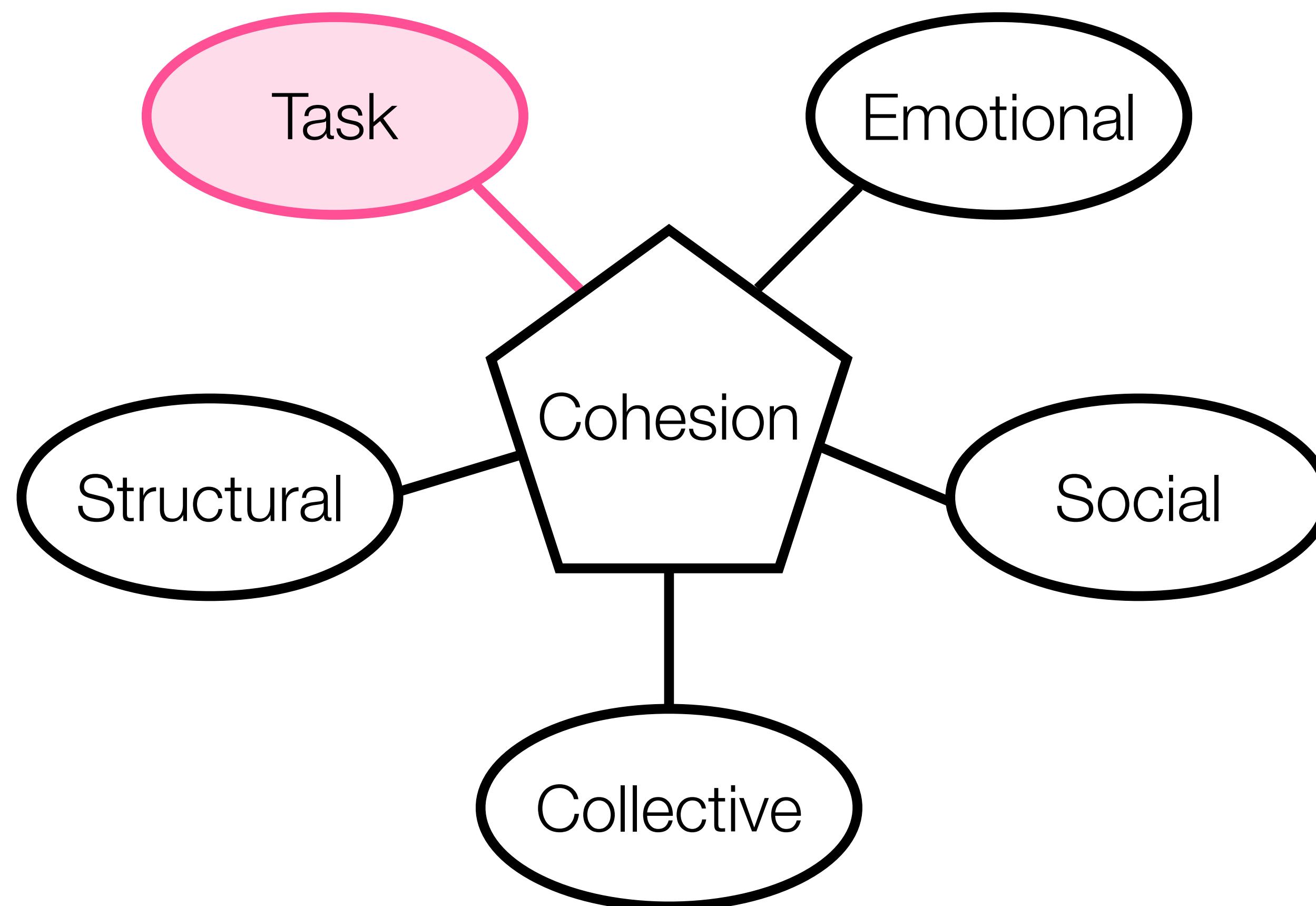
*How can we endow a robotic teammate with social capabilities to improve the **cohesive alliance** in a multi-party setting with humans?*

What is Cohesion?



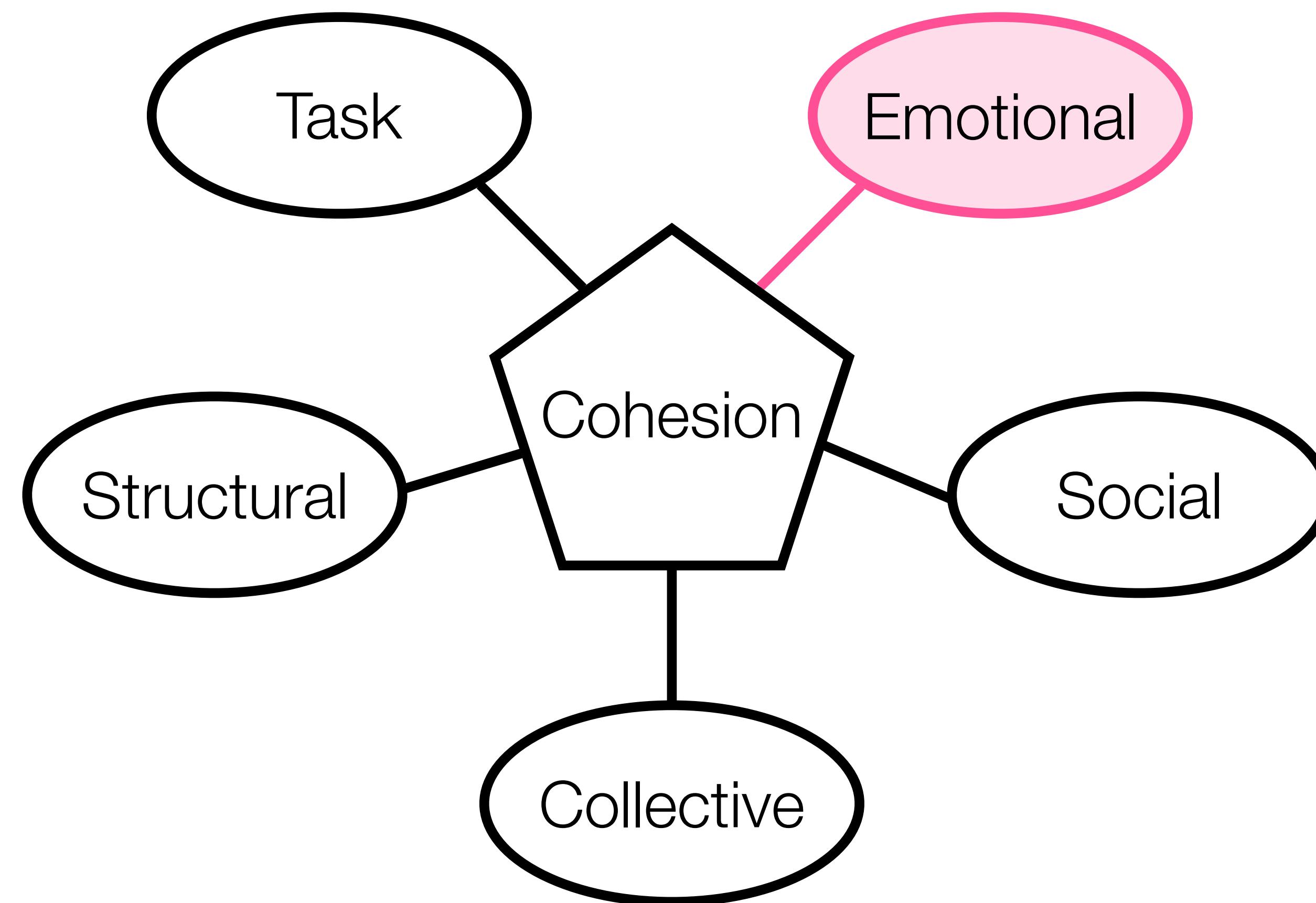
10

What is Task Cohesion?



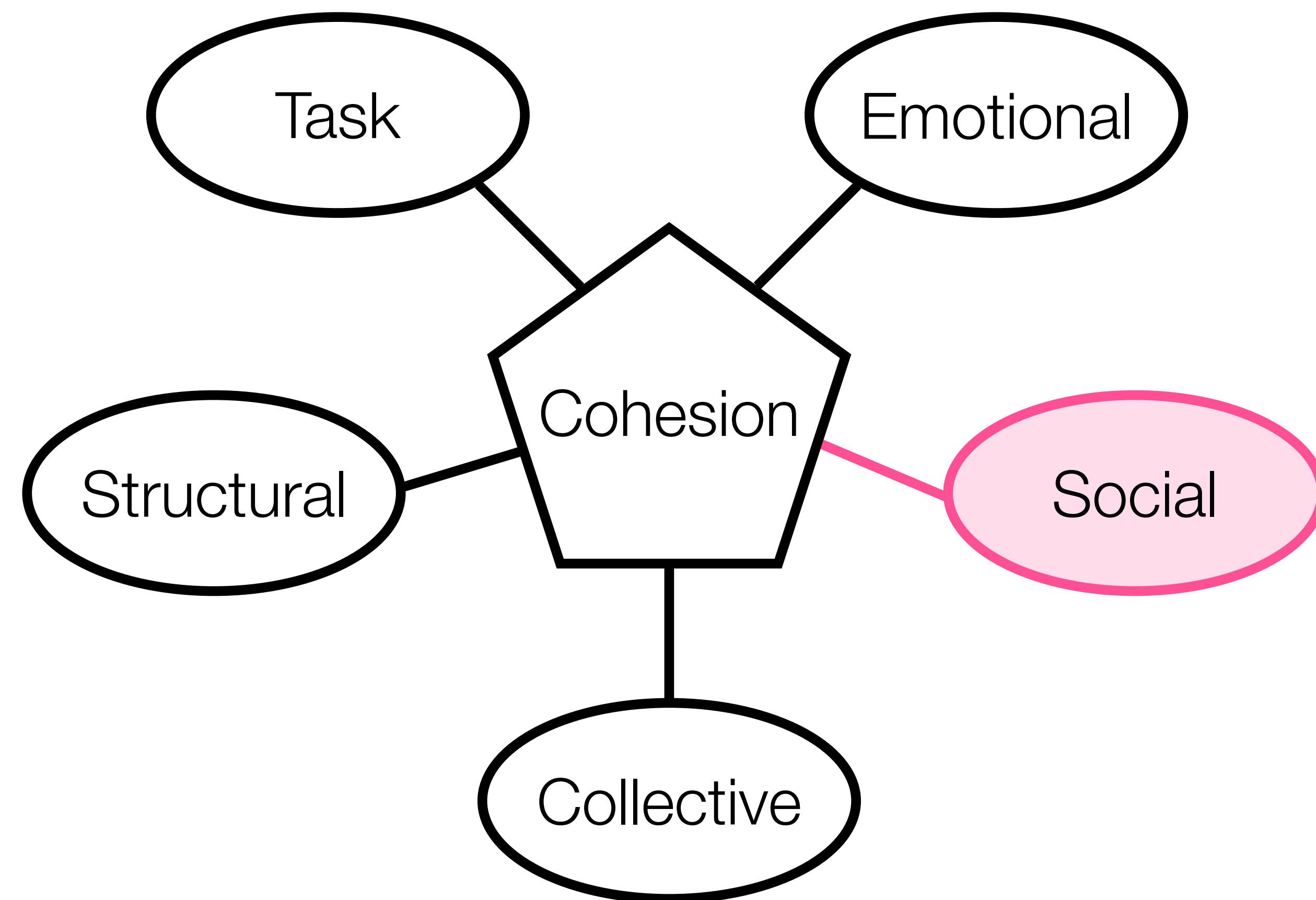
11

What is Emotional Cohesion?



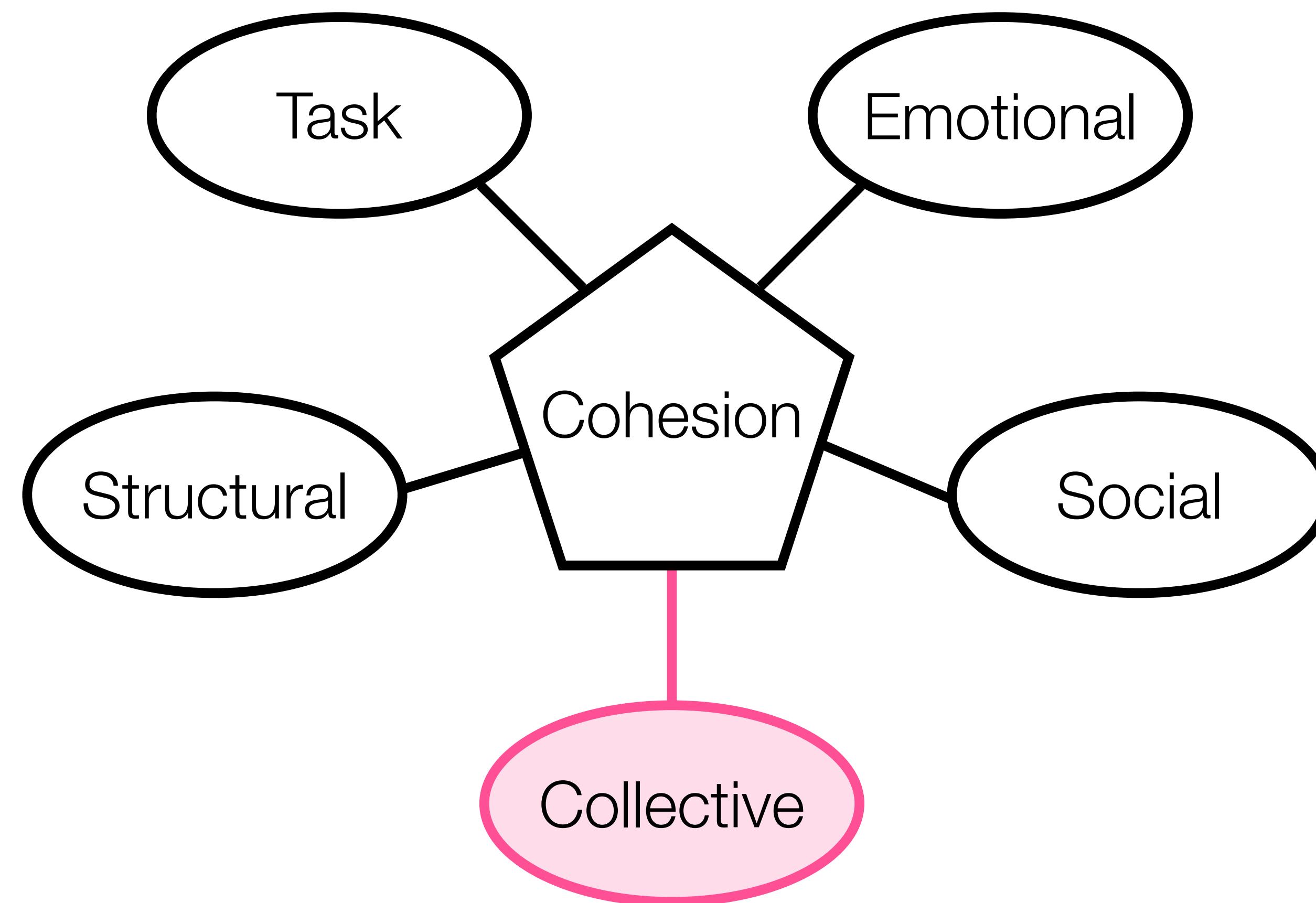
12

What is Social Cohesion?



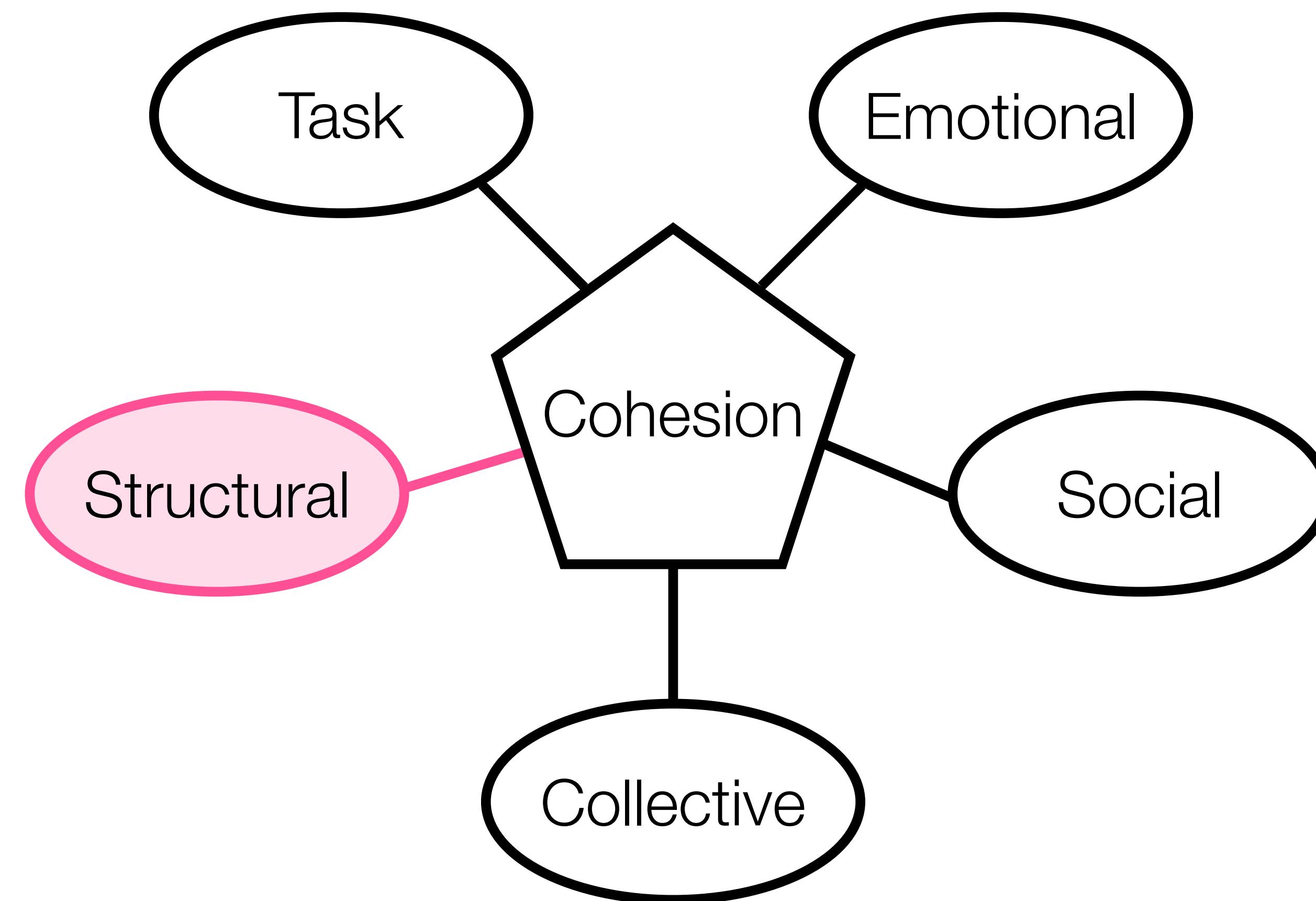
13

What is Collective Cohesion?



14

What is Structural Cohesion?



15

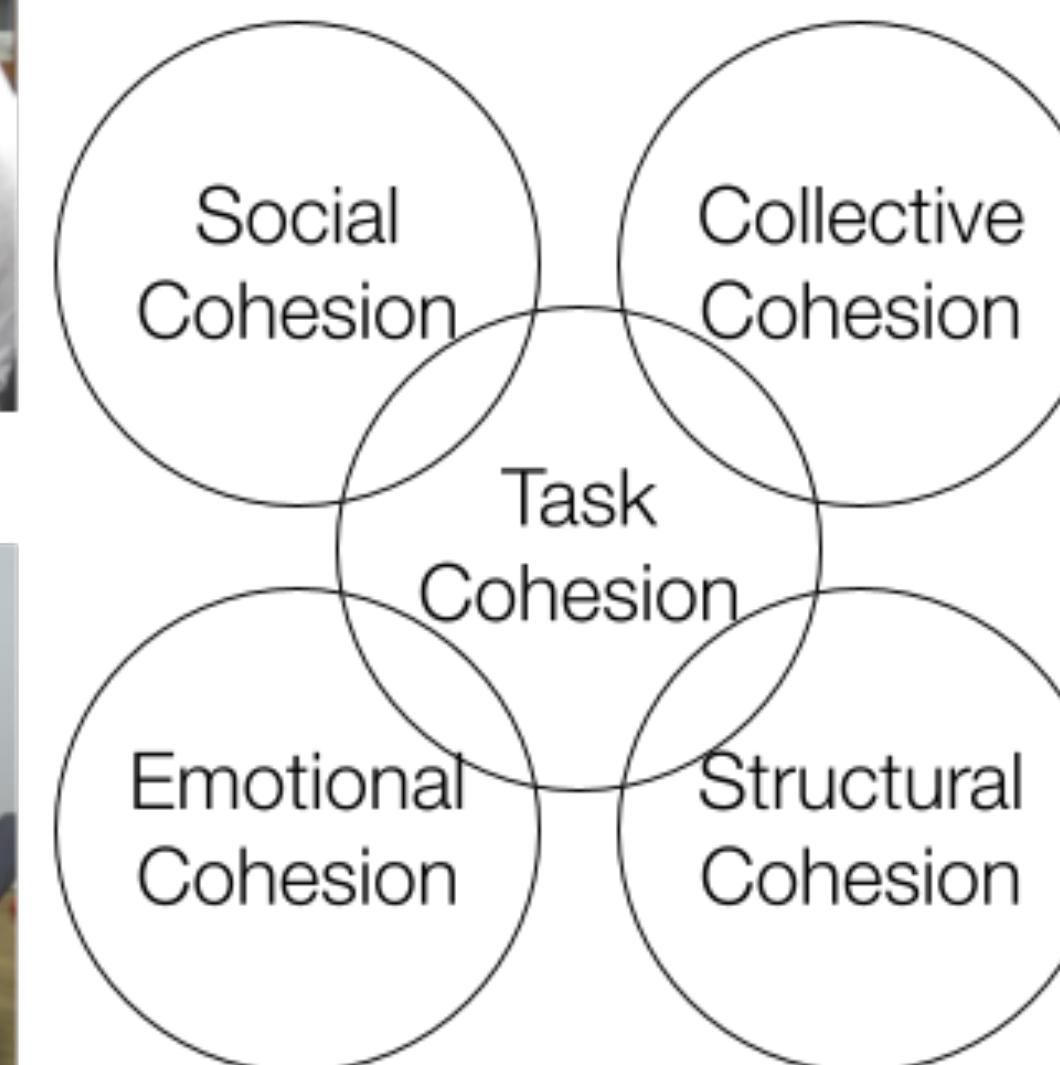
Research Plan



(a) Project I



(c) Project III



(b) Project II

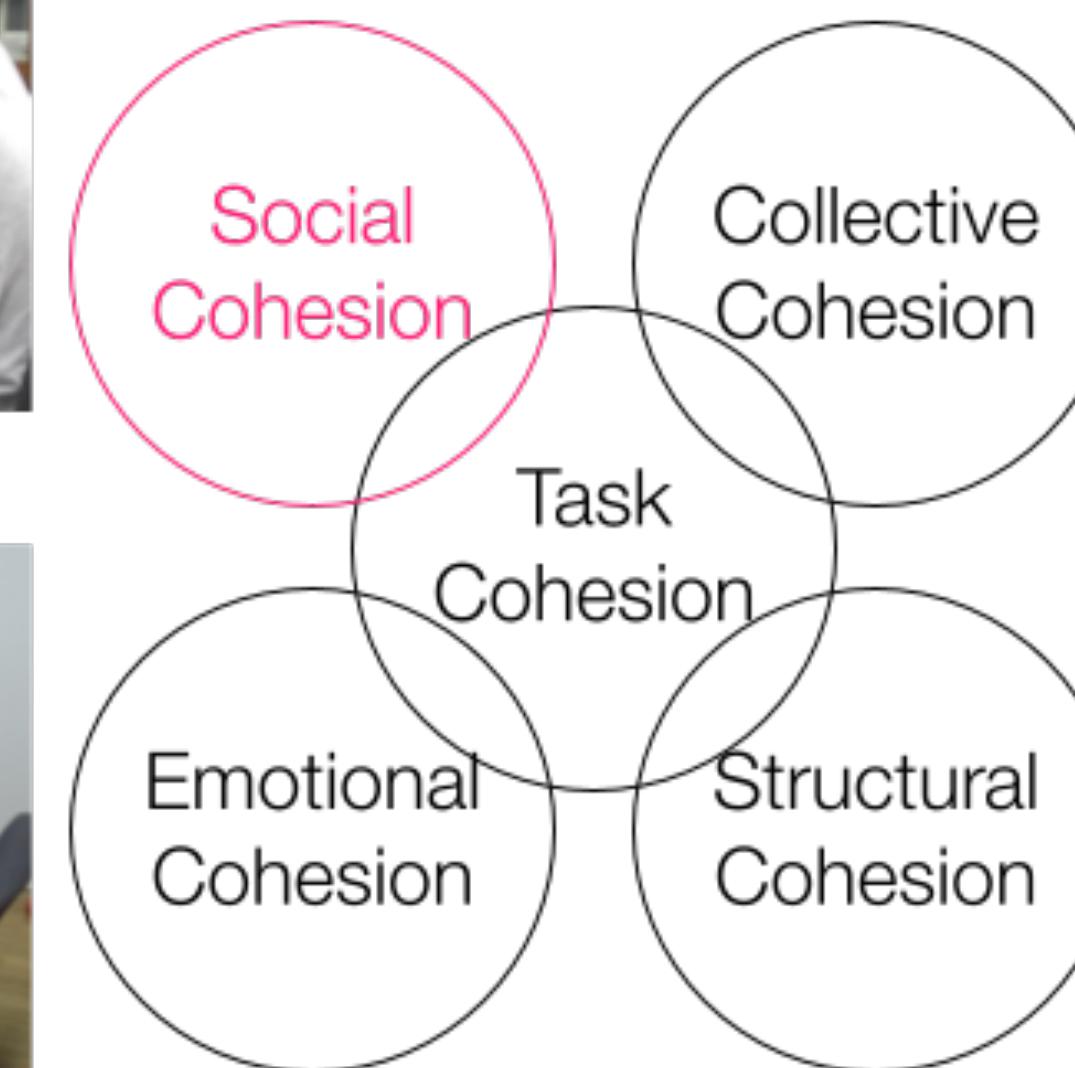


(d) Project IV

Research Plan



(a) Project I



(b) Project II



(c) Project III



(d) Project IV

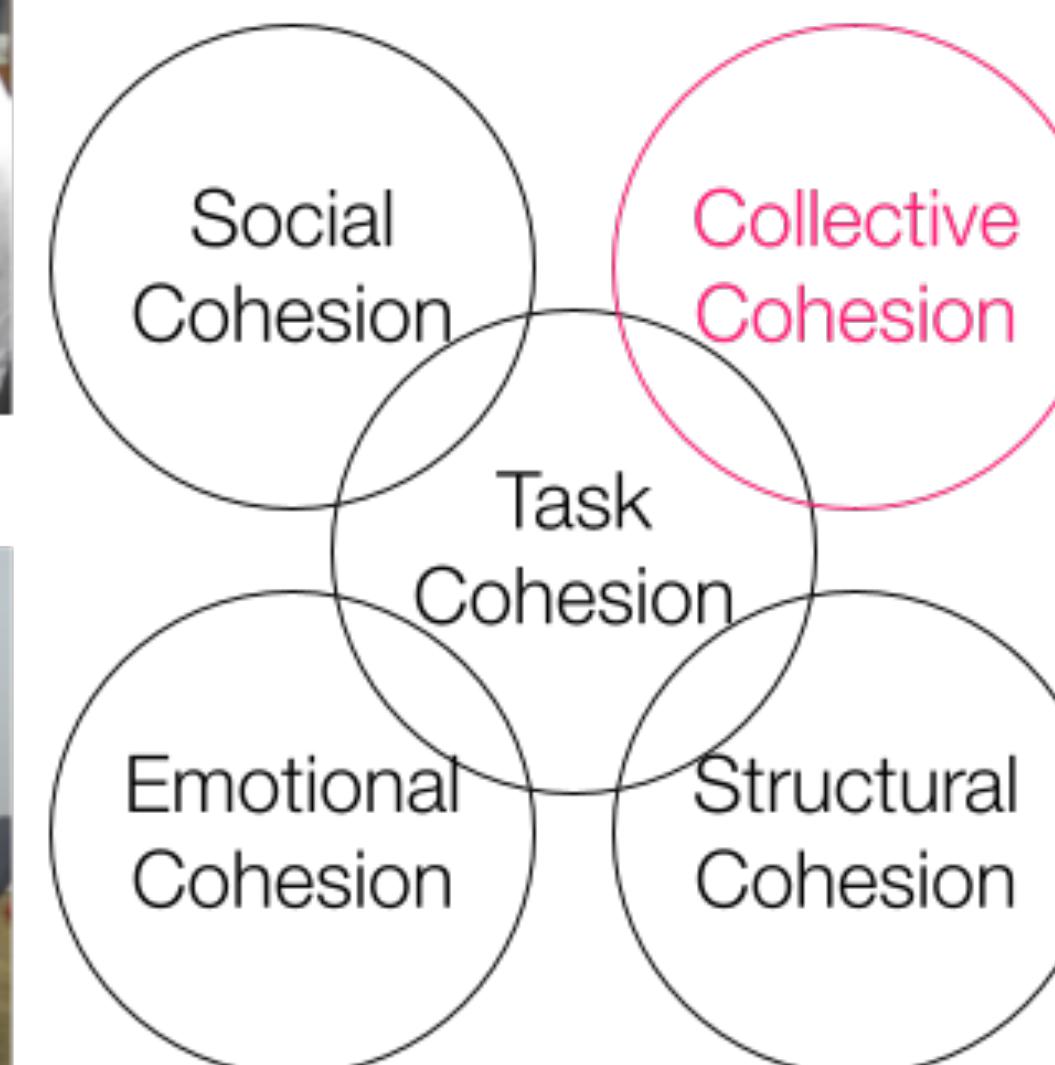
Research Plan



(a) Project I



(c) Project III



(b) Project II



(d) Project IV

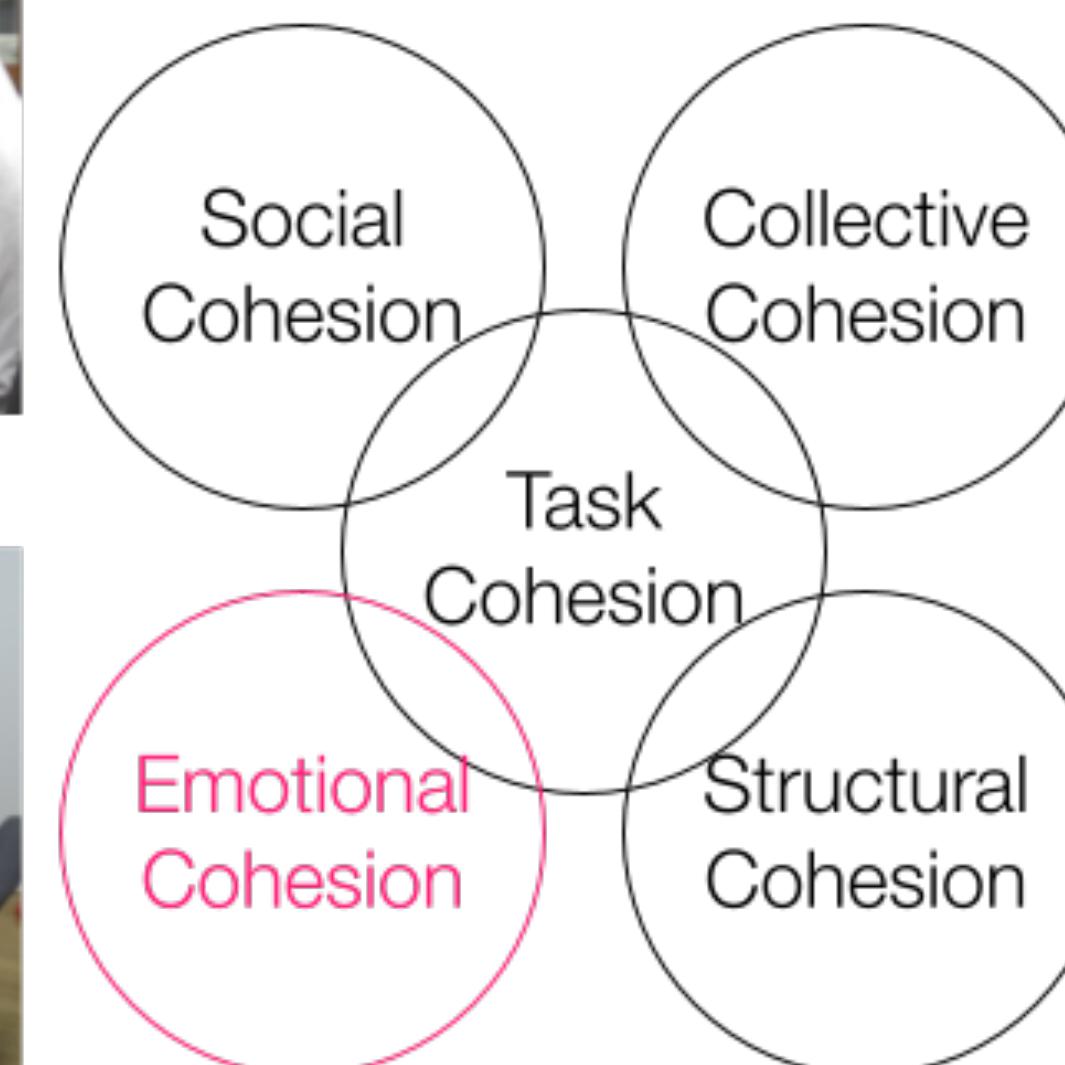
Research Plan



(a) Project I



(c) Project III



(b) Project II



(d) Project IV

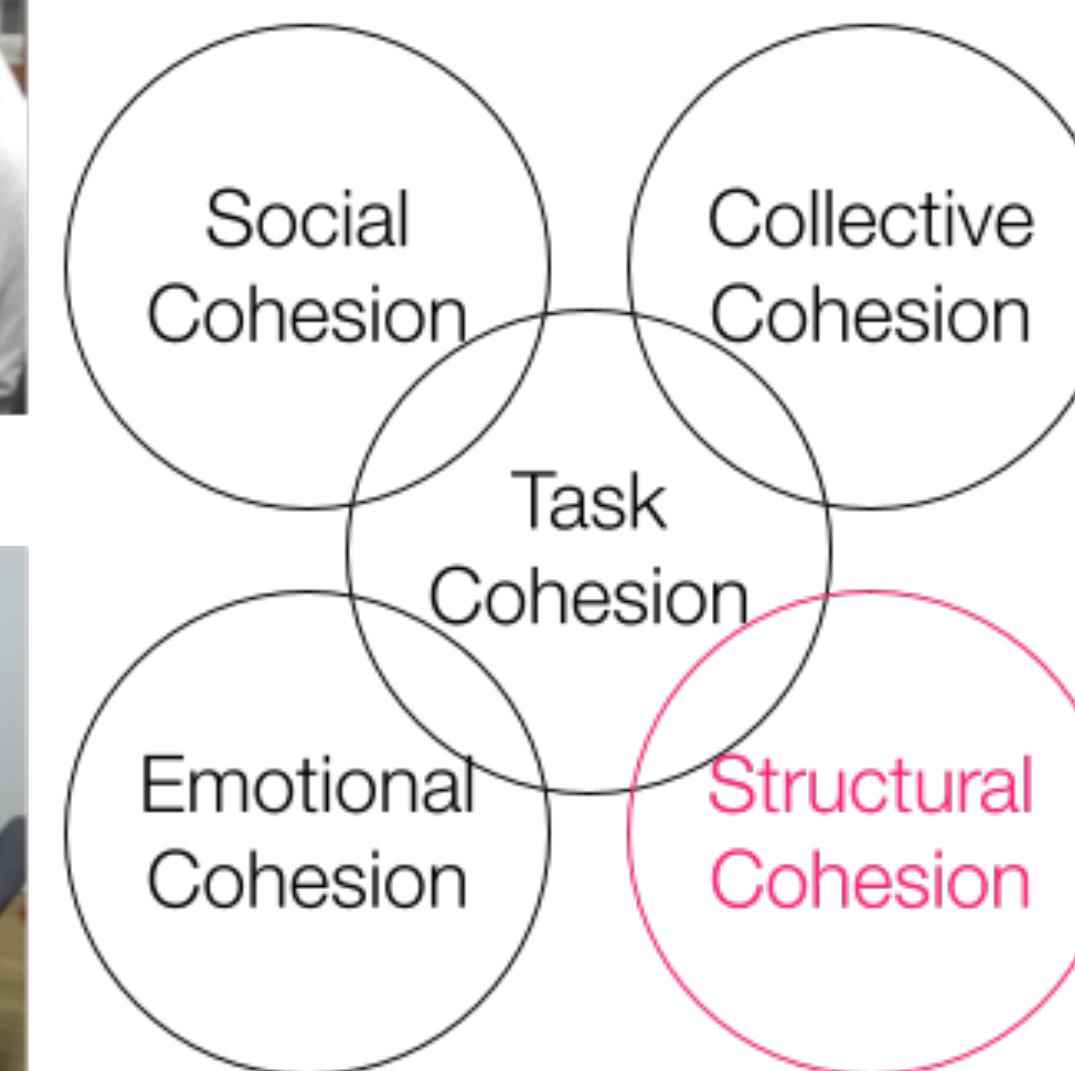
Research Plan



(a) Project I



(c) Project III



(b) Project II

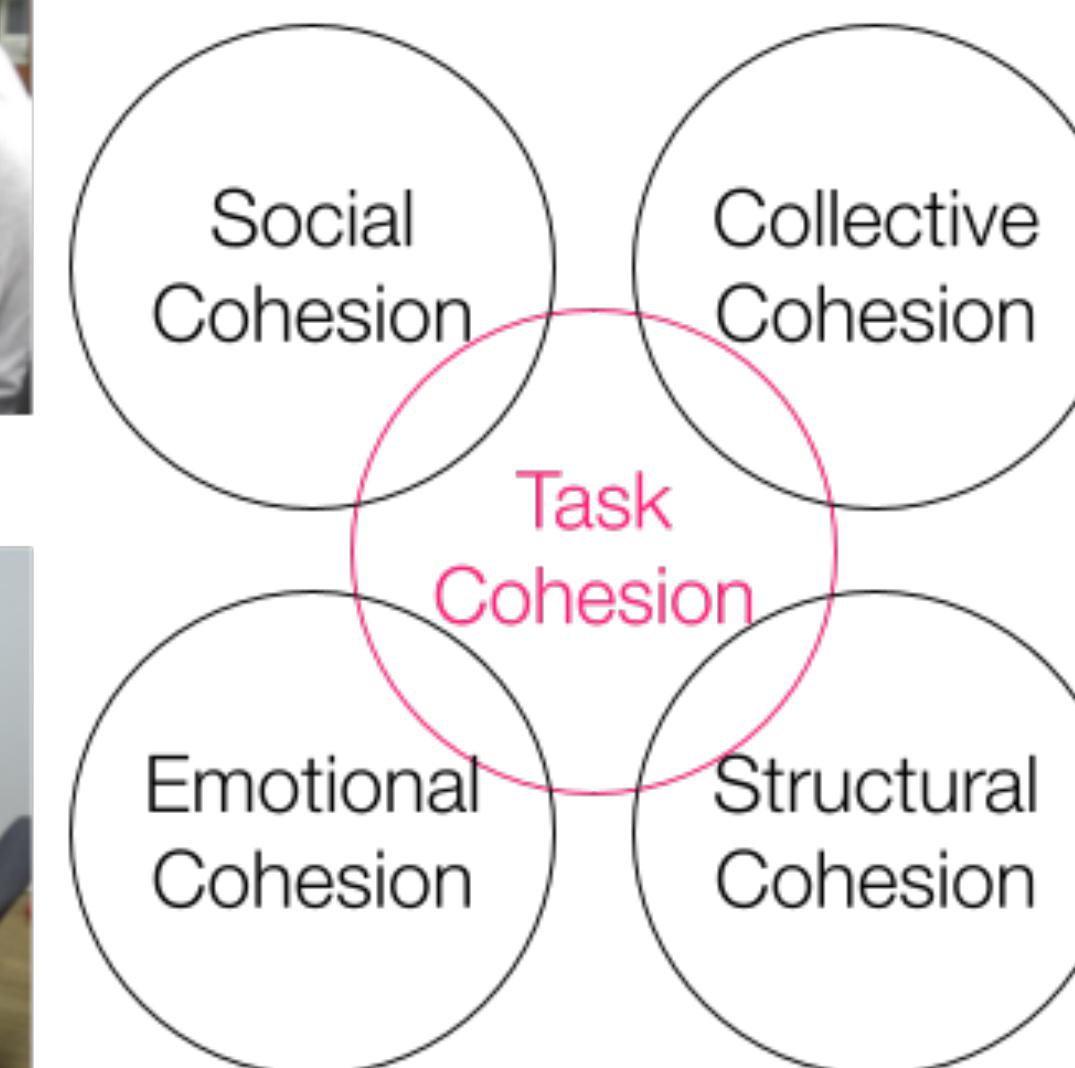


(d) Project IV

Research Plan



(a) Project I



(c) Project III



(b) Project II



(d) Project IV

Project I - Membership Preferences & Team Formation

Project Goal & Research Questions

Social Cohesion

- How do relationships and attractions develop towards robotic teammates?
- What traits do people prefer on robotic teammates?

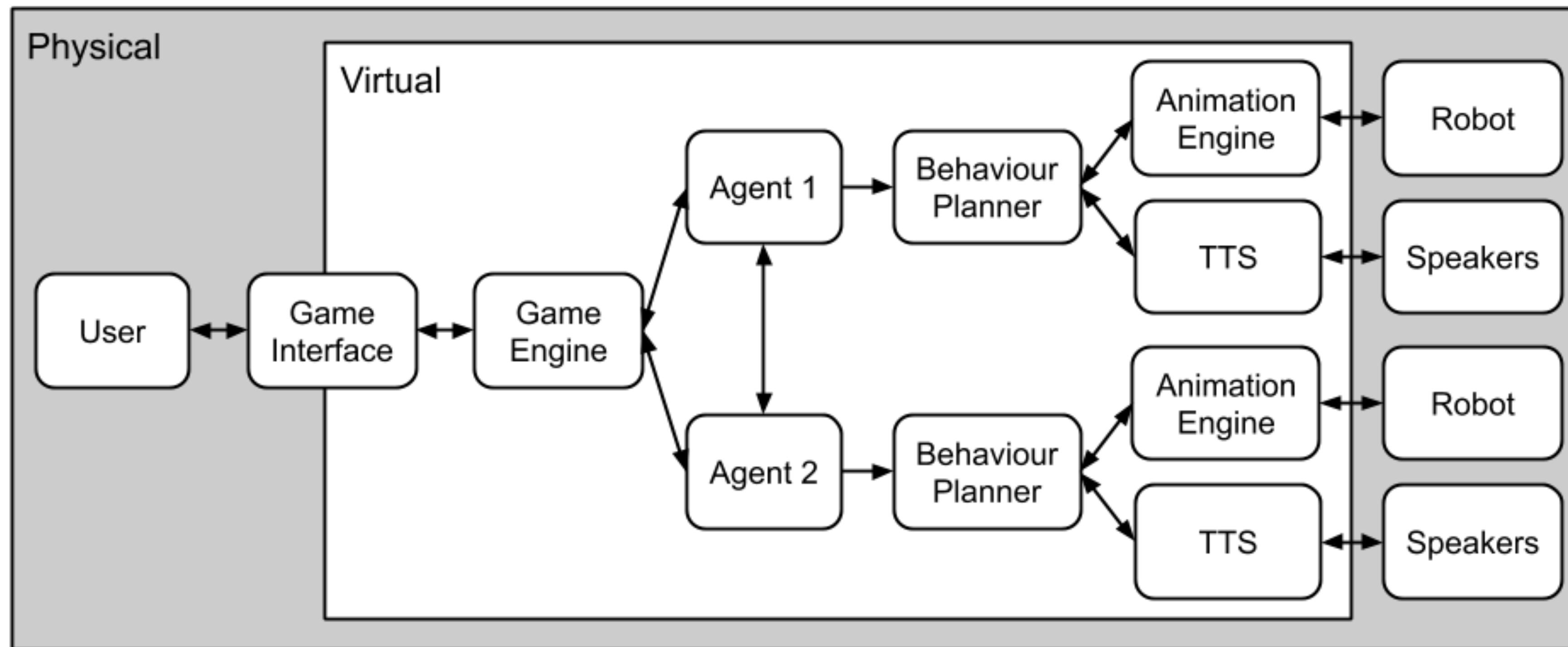
GROUPS OF HUMANS AND ROBOTS

Understanding membership preferences
and team formation

FILIPA CORREIA, SOFIA PETISCA, PATRÍCIA ALVES-OLIVEIRA,
TIAGO RIBEIRO, FRANCISCO S. MELO, ANA PAIVA

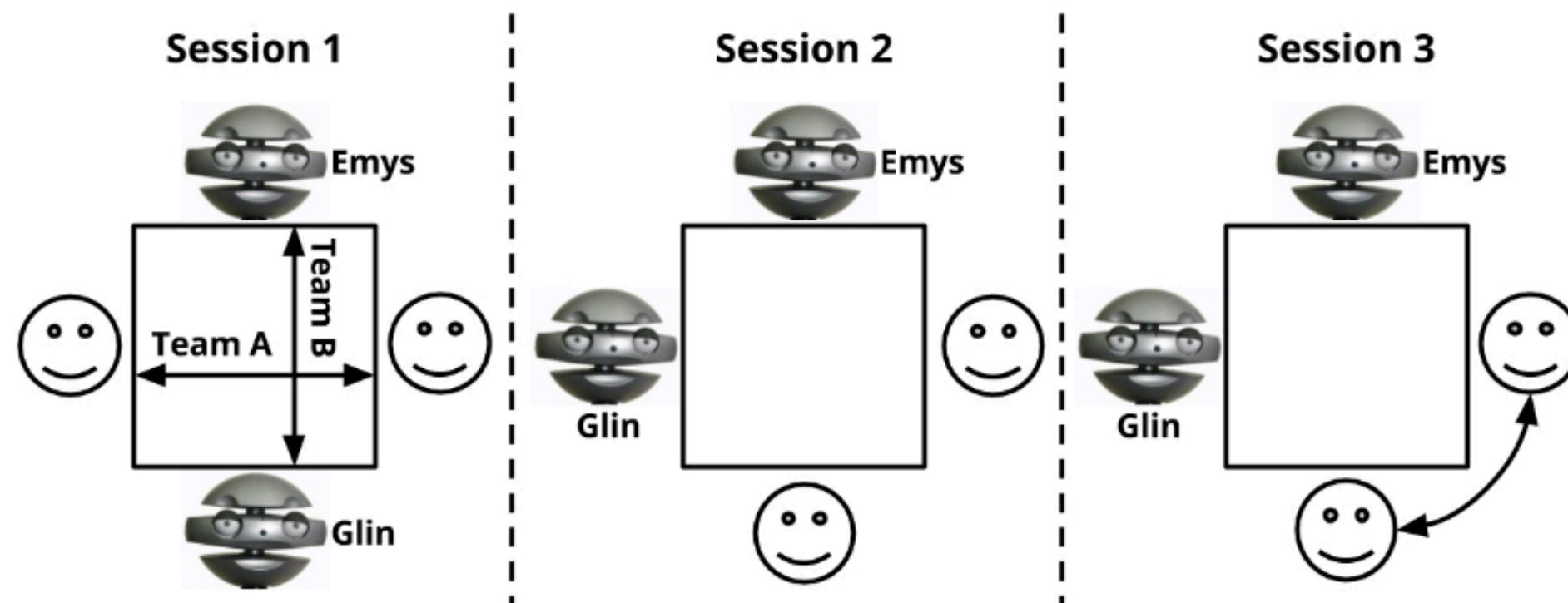
ROBOTICS: SCIENCE AND SYSTEMS, 2017

Architecture for 2 autonomous robots



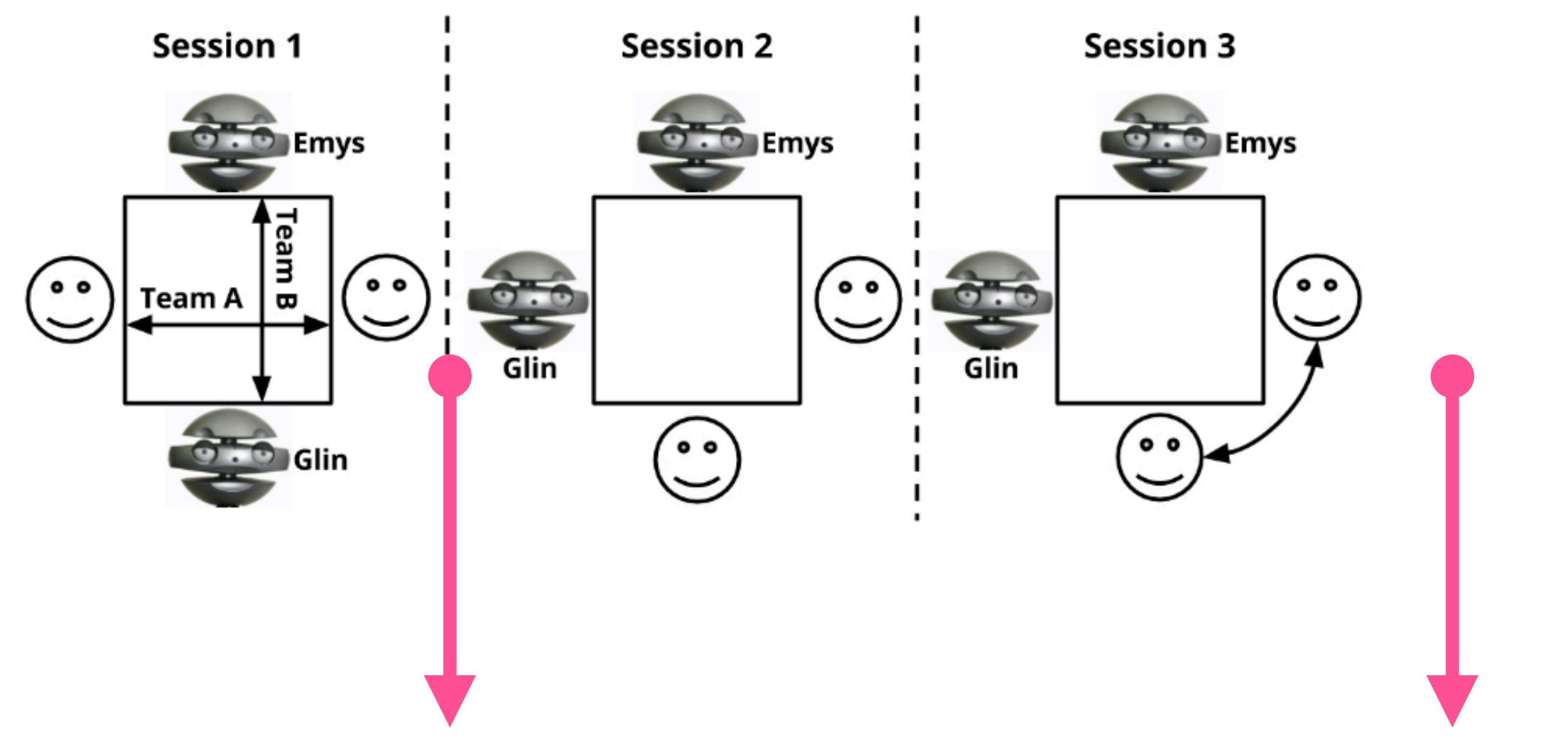
User Study

- Card game (2 VS 2)
- 3 sessions (1h30)



User Study

Which robot will people prefer to partner with?

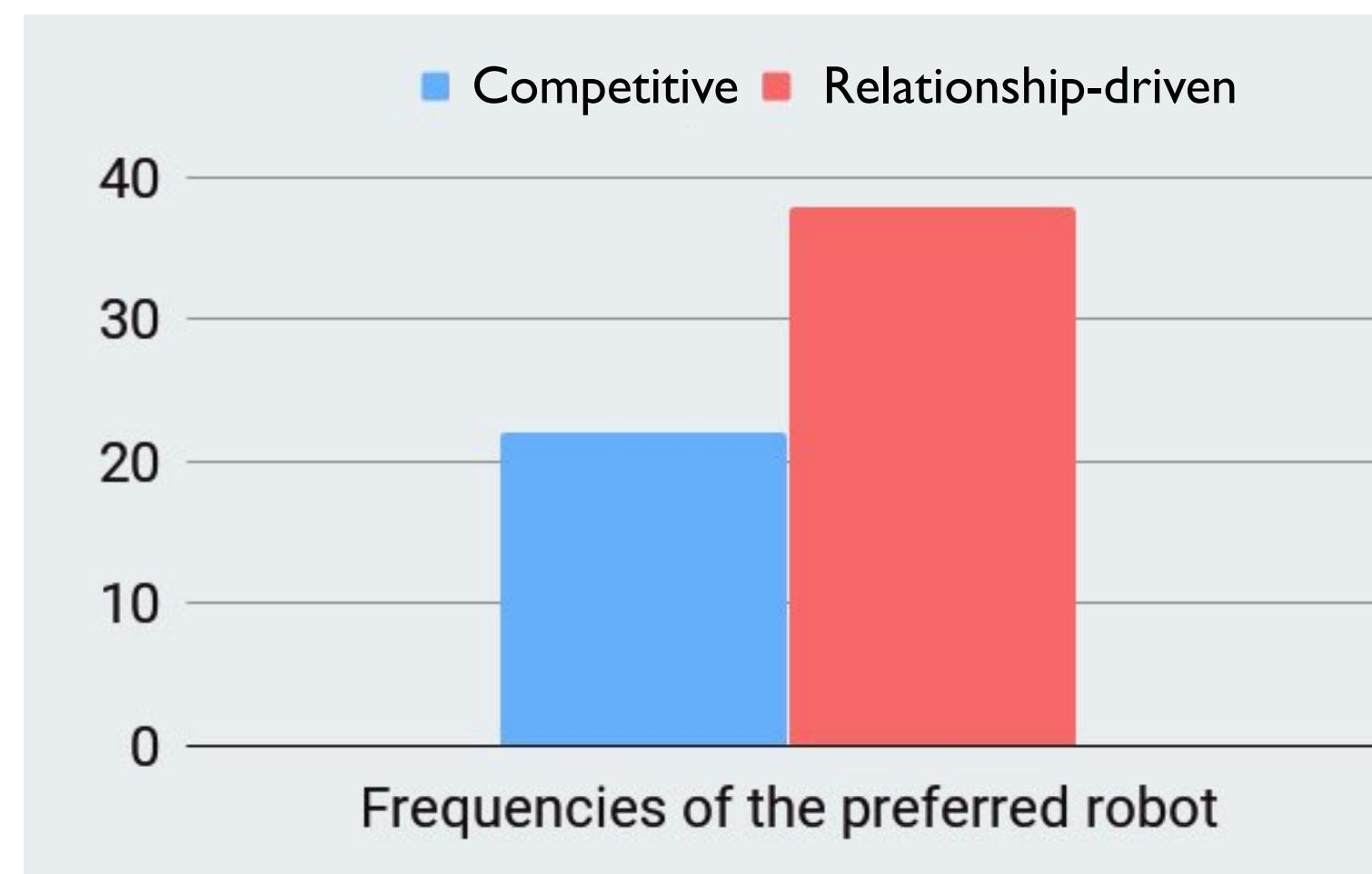


First choice of
robotic partner

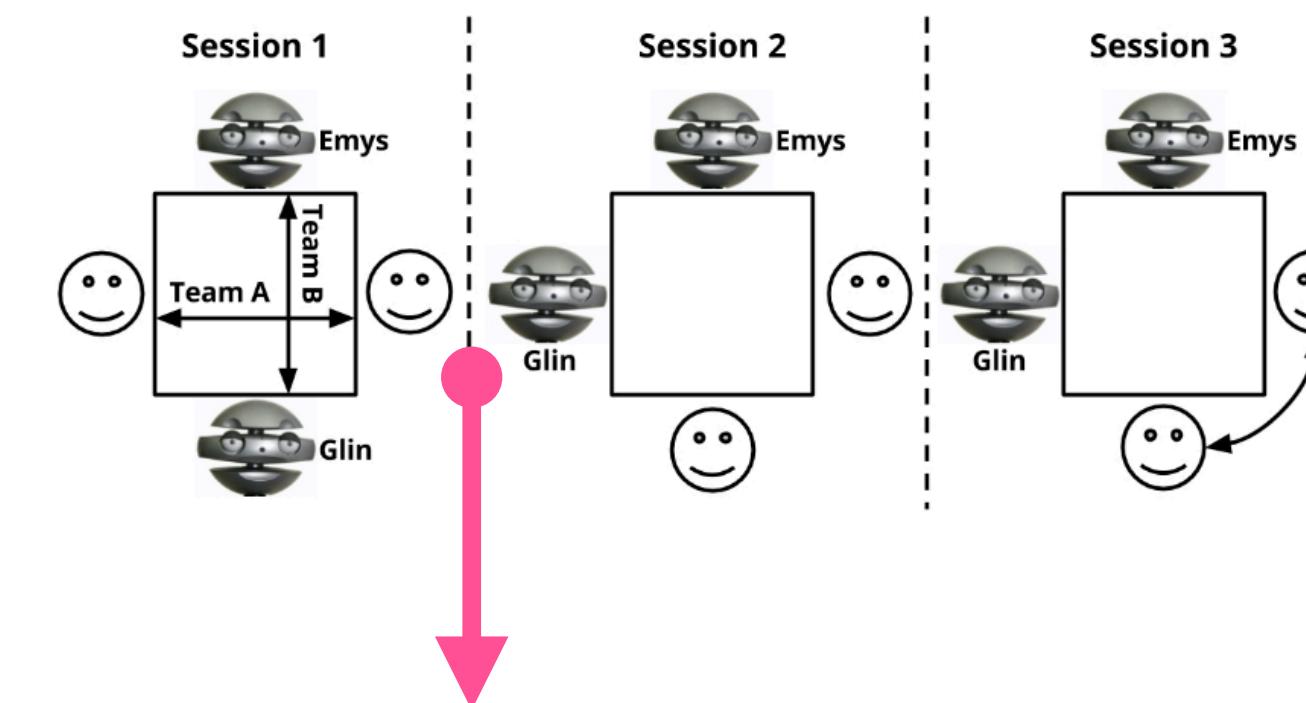
Last choice of
robotic partner

User Study - Results

In the first choice...

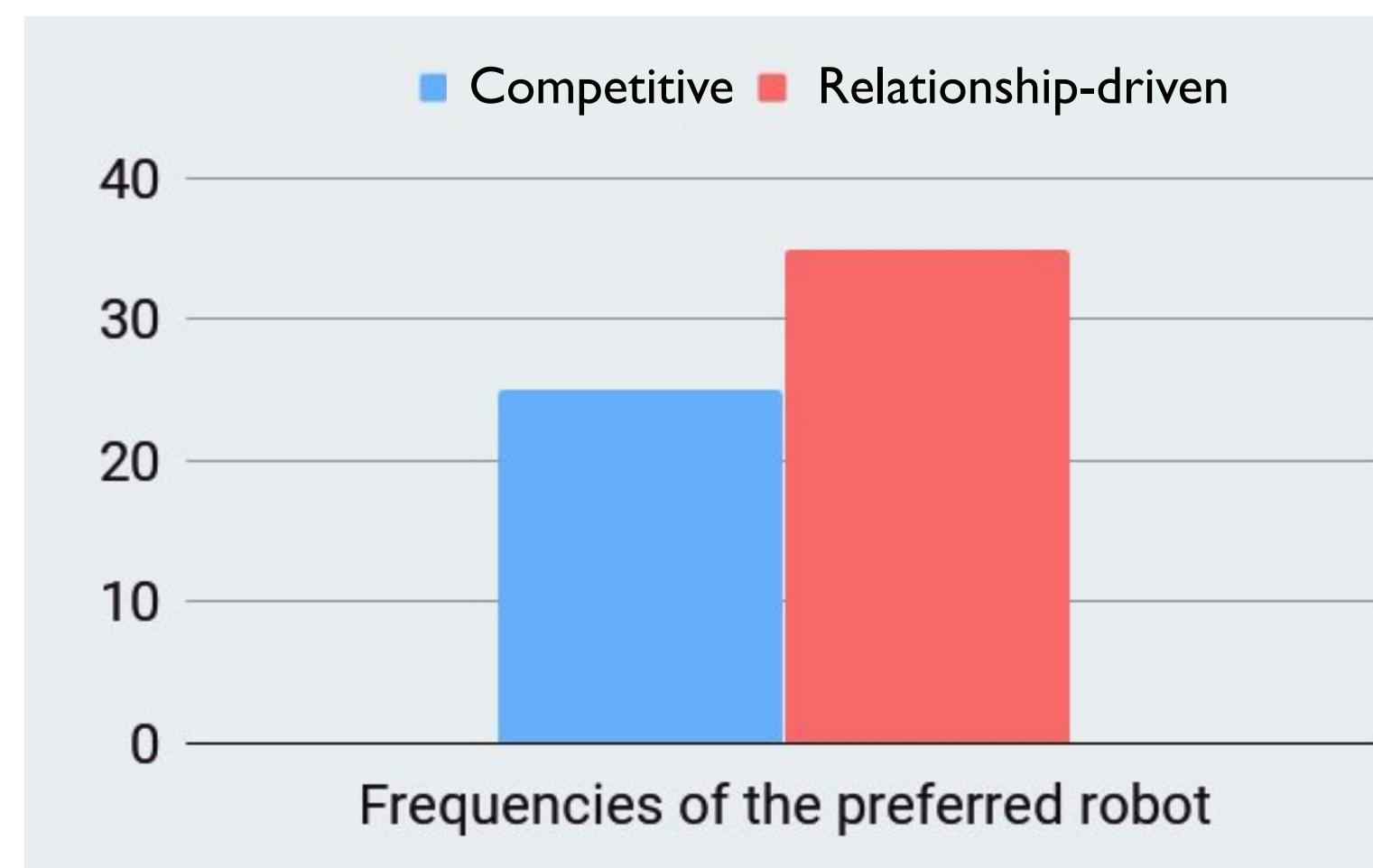


p=0.039

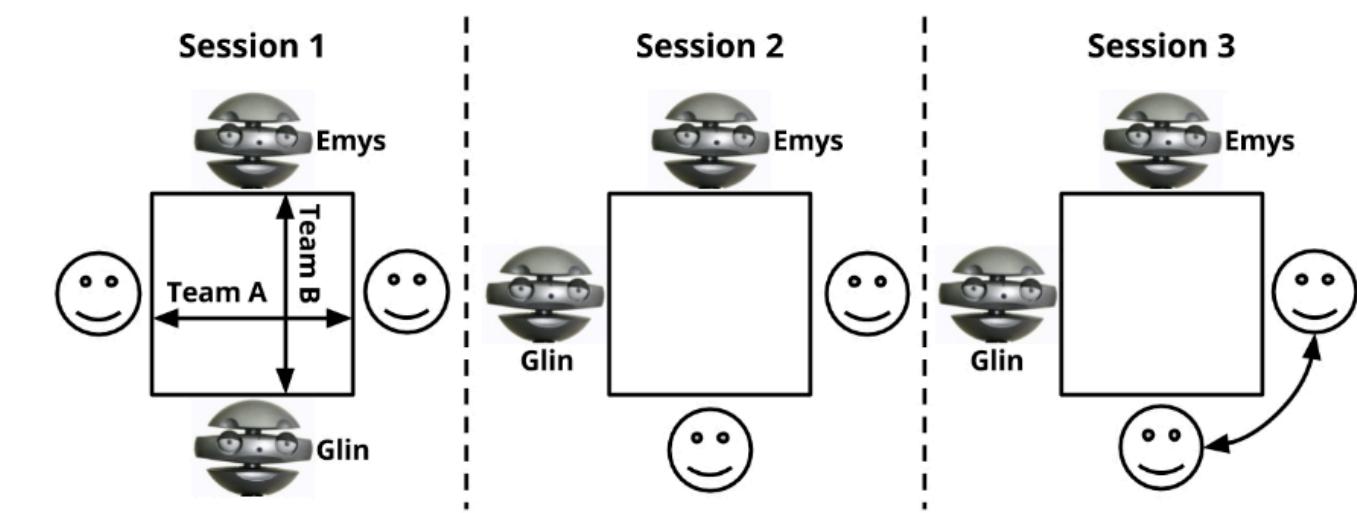


User Study - Results

In the last choice...



$p=0.197$

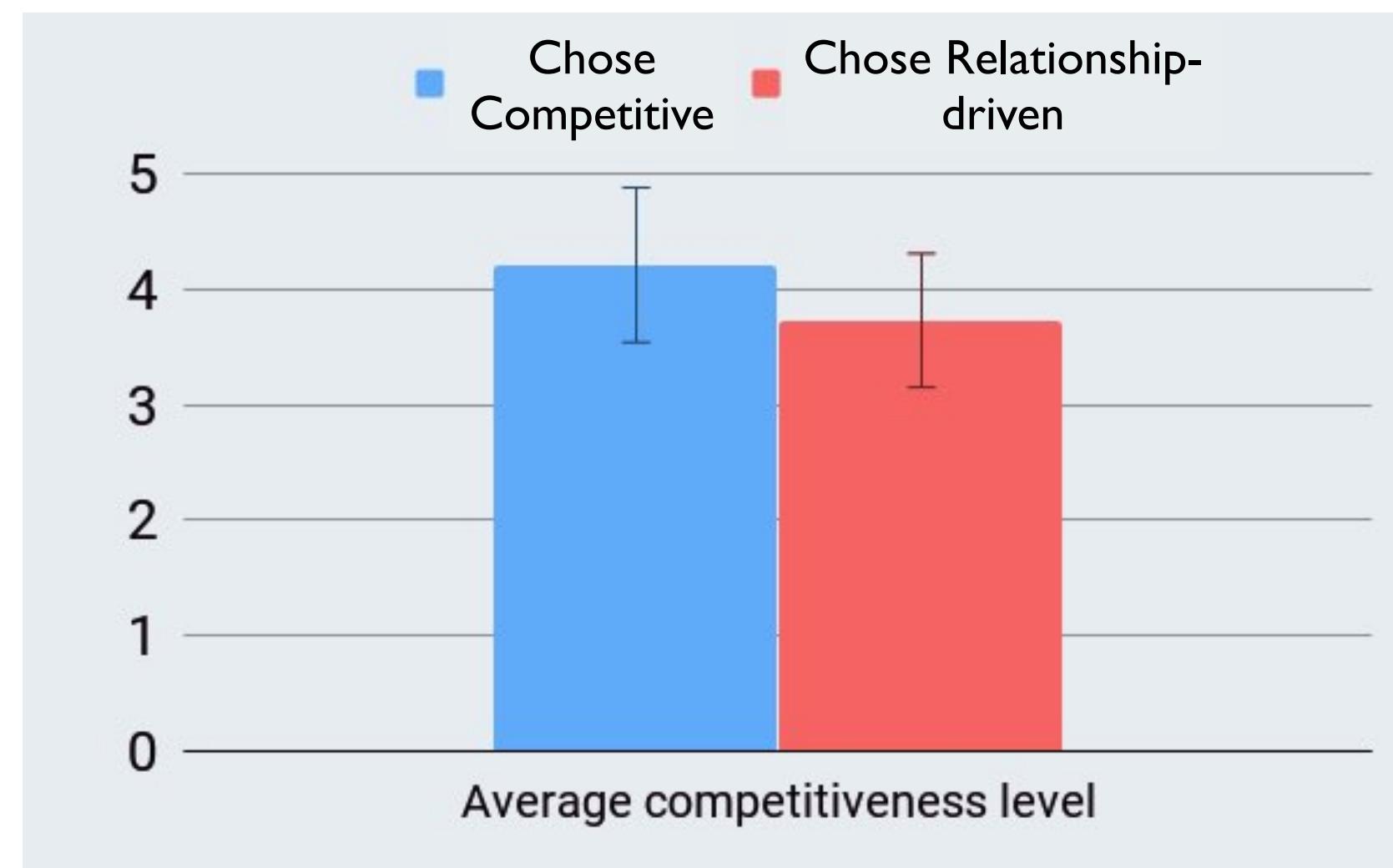


Last choice of
robotic partner

User Study - Results

Why?

- People's competitiveness was significantly different



p=0.005

User Study - Results

Why?

- Significant association between the performance of the robots and people's preference ($p=0.008$)

User Study - Take-away Message

Membership preferences in a competitive game context seem to be guided by personal characteristics and by the team performance.

The Learning-Goal Theory can be used to design social behaviours of robotic teammates in order to foster human-robot teamwork attractions or social cohesion.

Other follow-up work

- We performed a behavioural analysis on collected data from the second user study, where we analysed socioemotional and task-oriented behaviours (Bales IPA)

Project II - Pro-sociality in human-robot teams

Project Goal & Research Questions

Collective Cohesion

- How do people perceive pro-social and selfish actions of robotic teammates?
- How can the perception of those robots be affected by the outcome of team?
- Does the outcome of the team affect how humans identify with the team and trust it?

User Study

- Team of 3
 - 2 autonomous robots
 - 1 person
- Collective Risk Dilemma - For The Record
 - Common Goal - “avoid the team’s catastrophe” - **to cooperate**
 - Individual Goal - “have the highest individual score” - **to defect**

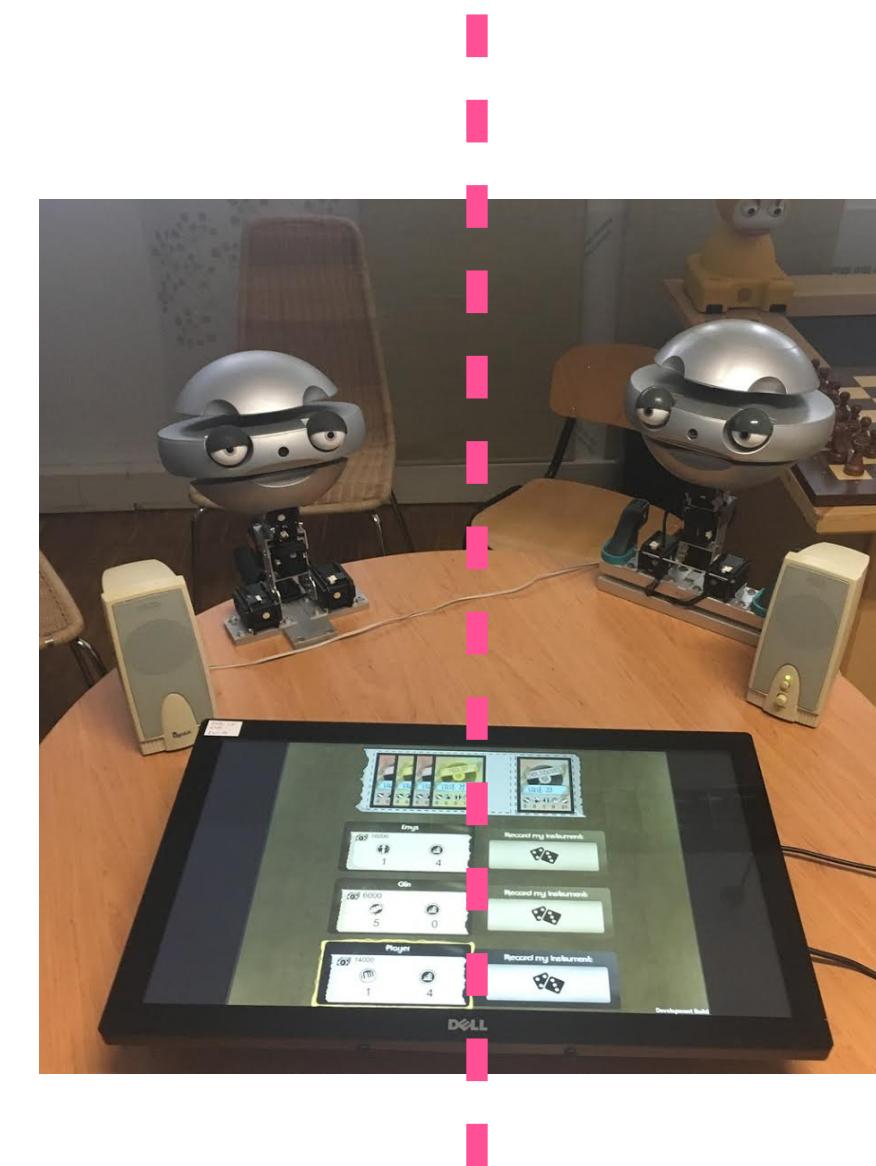


Experimental Design

- Mixed experimental design
 - Within-subjects variable - strategy of the robots

Cooperator

Defector



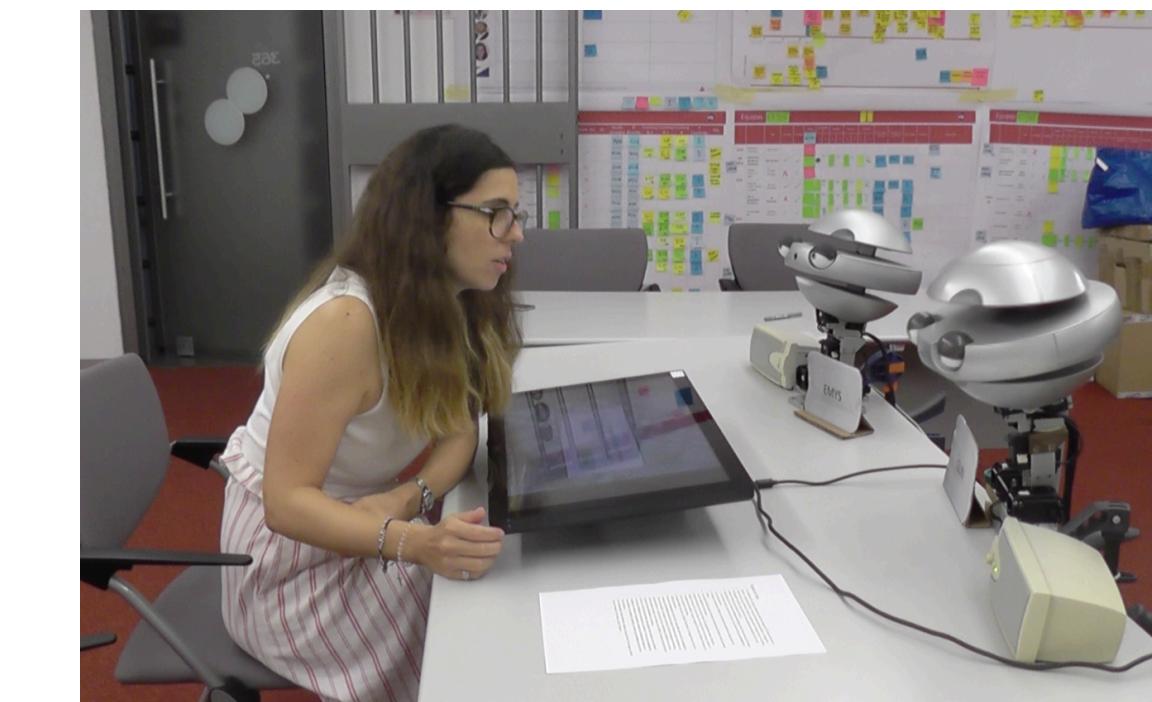
Experimental Design

- Mixed experimental design
 - Within-subjects variable - strategy of the robots
 - Between-subjects variable - game result

Winning



Losing

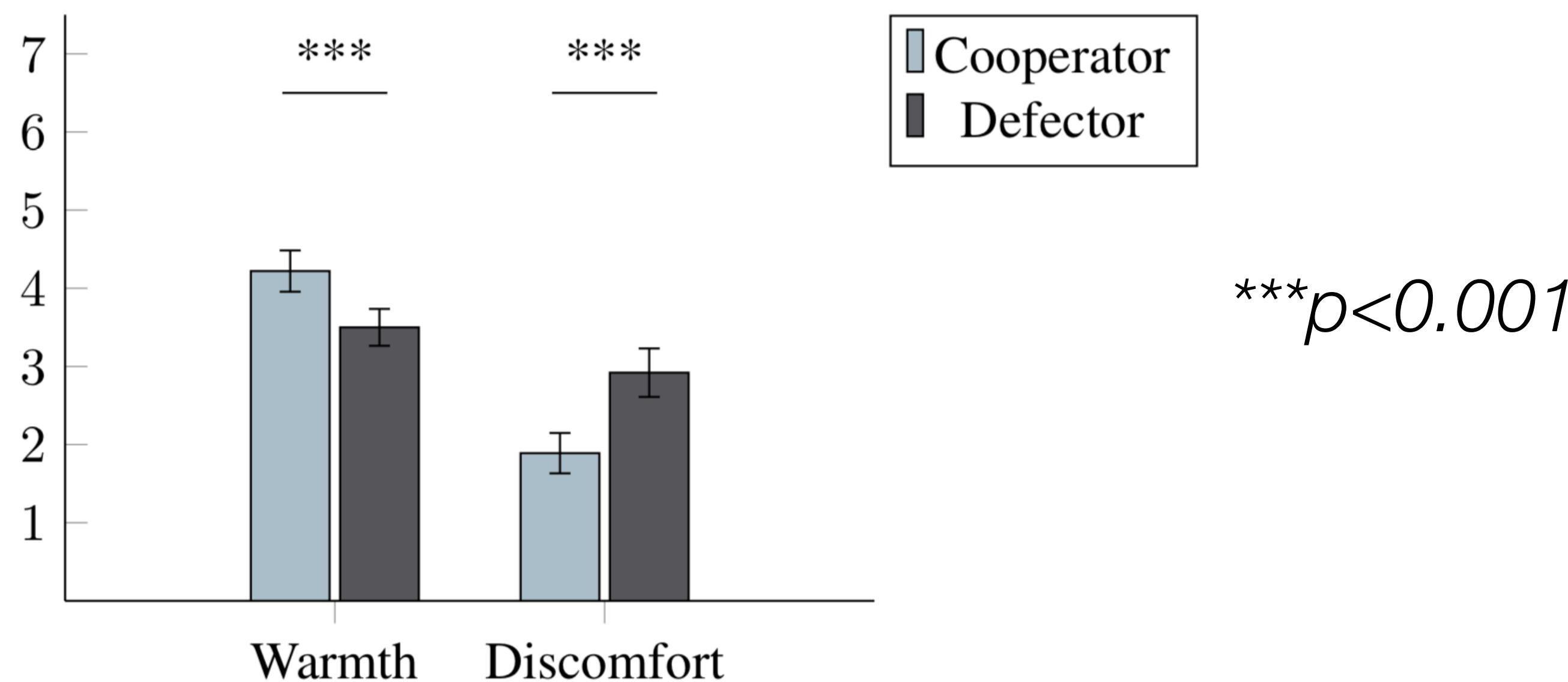




The common resource is a musical band with a collective goal to record and sell albums.

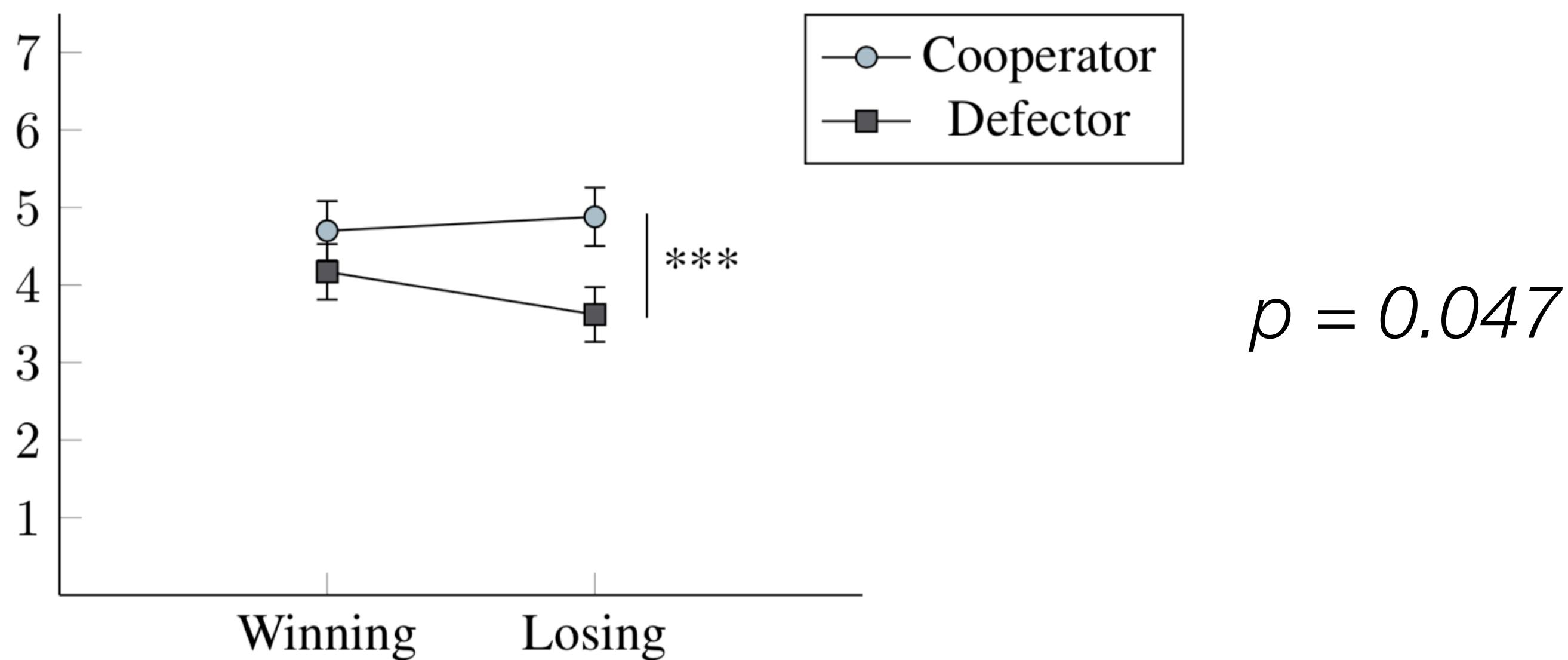
User Study - Results

Social attributes of warmth and discomfort (RoSAS)



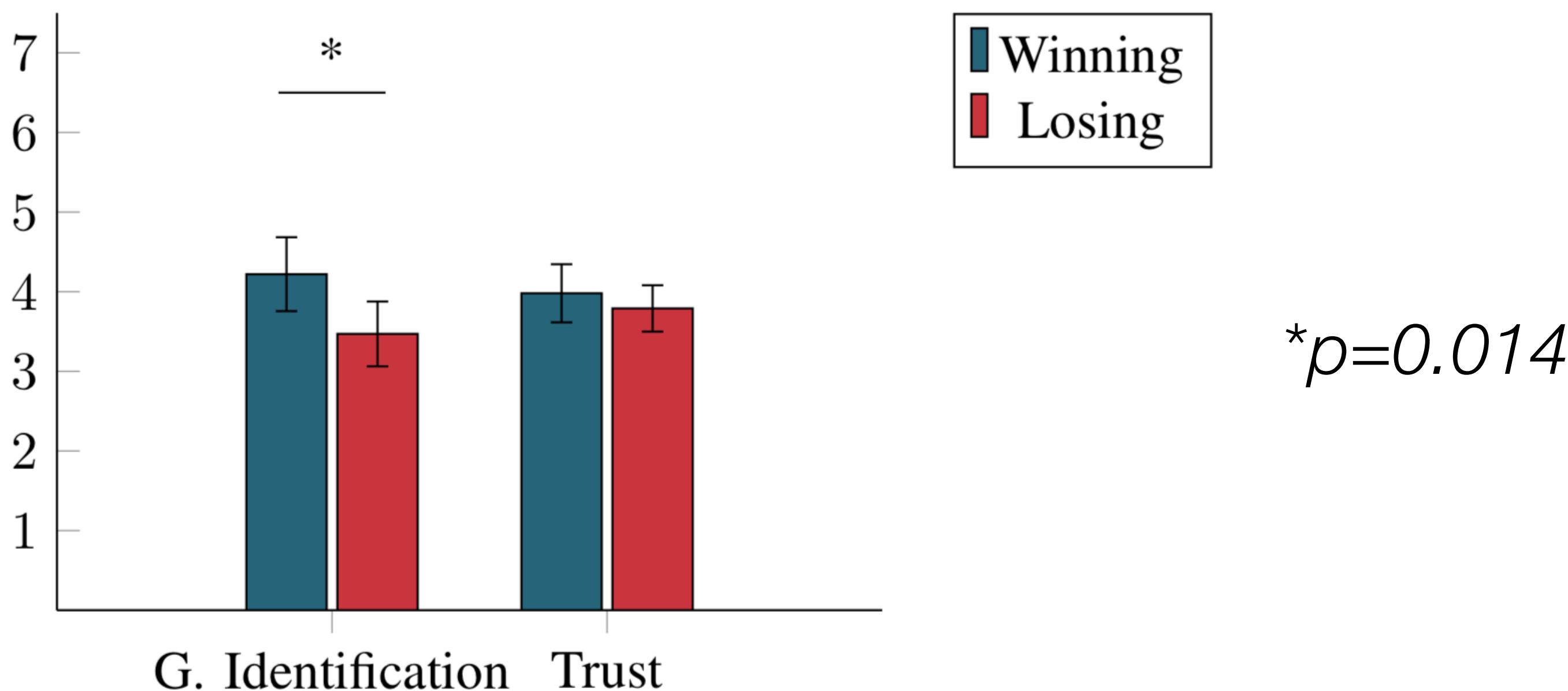
User Study - Results

Social attribute of competence (RoSAS)



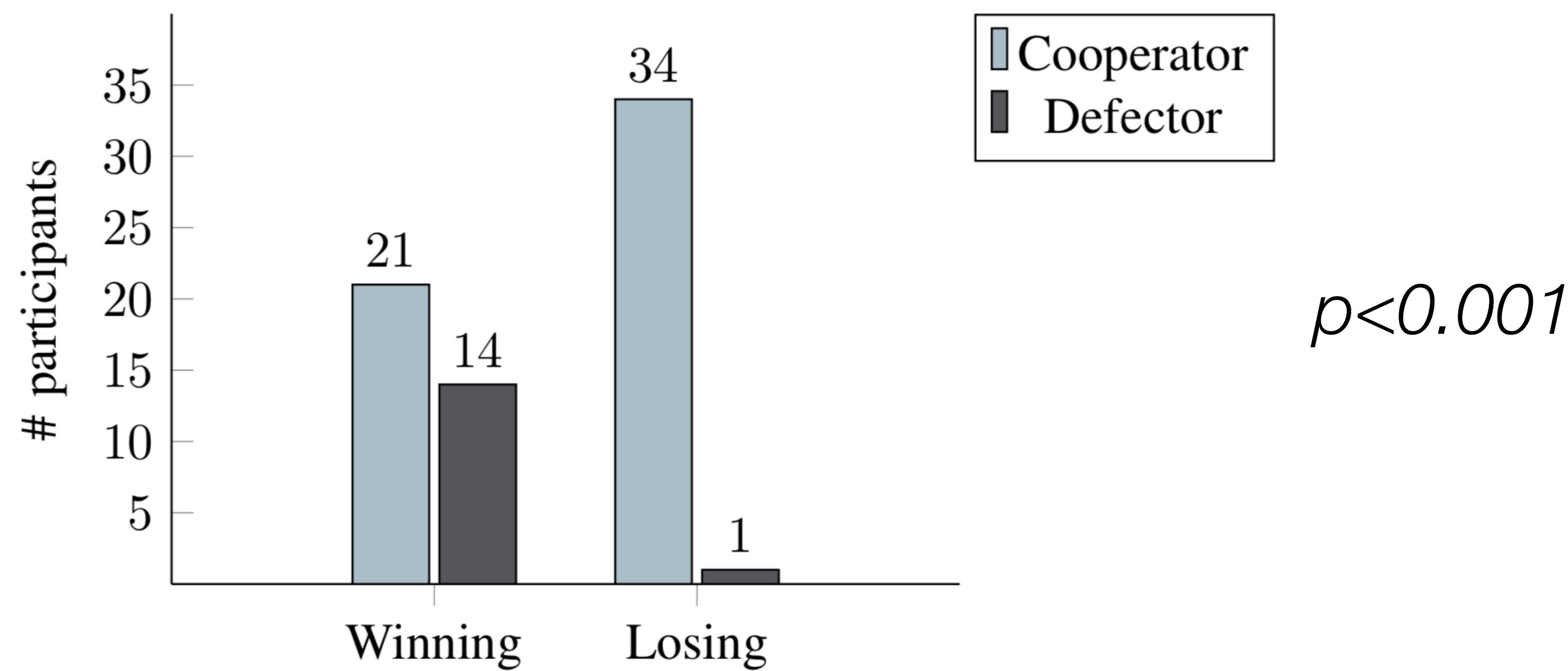
User Study - Results

Group measures



User Study - Results

Preference for a hypothetical future game



User Study - Take-away Message

The outcome of the game had strong impact on people's perceptions of the robot and the team.

Positive outcomes can “forgive” selfishness...

Other follow-up work

- Can the display of verbal criticism encourage people to change selfish actions?
- What are the evolutionary advantages of selecting cooperative partners only when a previous game was lost?
- What is the impact of embodied features?
- What is the role of agents' transparency?

Correia, F., Chandra, S., Mascarenhas, S., Charles-Nicolas, J., Gally, J., Lopes, D., ... & Paiva, A. (2019, October). Walk the Talk! Exploring (Mis) Alignment of Words and Deeds by Robotic Teammates in a Public Goods Game. In 2019 28th IEEE International Conference on Robot and Human Interactive Communication **[RO-MAN]**

Santos, F. P., Mascarenhas, S., Santos, F. C., **Correia, F.**, Gomes, S., & Paiva, A. (2020). Picky losers and carefree winners prevail in collective risk dilemmas with partner ⁴⁵ selection. Autonomous Agents and Multi-Agent Systems, 34(2), 1-29. **[JAAMAS Journal]**

Correia, F., Gomes, S., Mascarenhas, S., Melo, F. S., & Paiva, A. (2020). The Dark Side of Embodiment-Teaming Up With Robots VS Disembodied Agents. Proceedings of Robotics: Science and Systems. **[RSS'20]**

Tulli, S., Correia, F., Mascarenhas, S., Gomes, S., Melo, F. S., & Paiva, A. (2019, May). Effects of agents' transparency on teamwork. In International Workshop on Explainable, Transparent Autonomous Agents and Multi-Agent Systems (pp. 22-37). Springer, Cham. **[ExTRAAMAS Special Issue]**

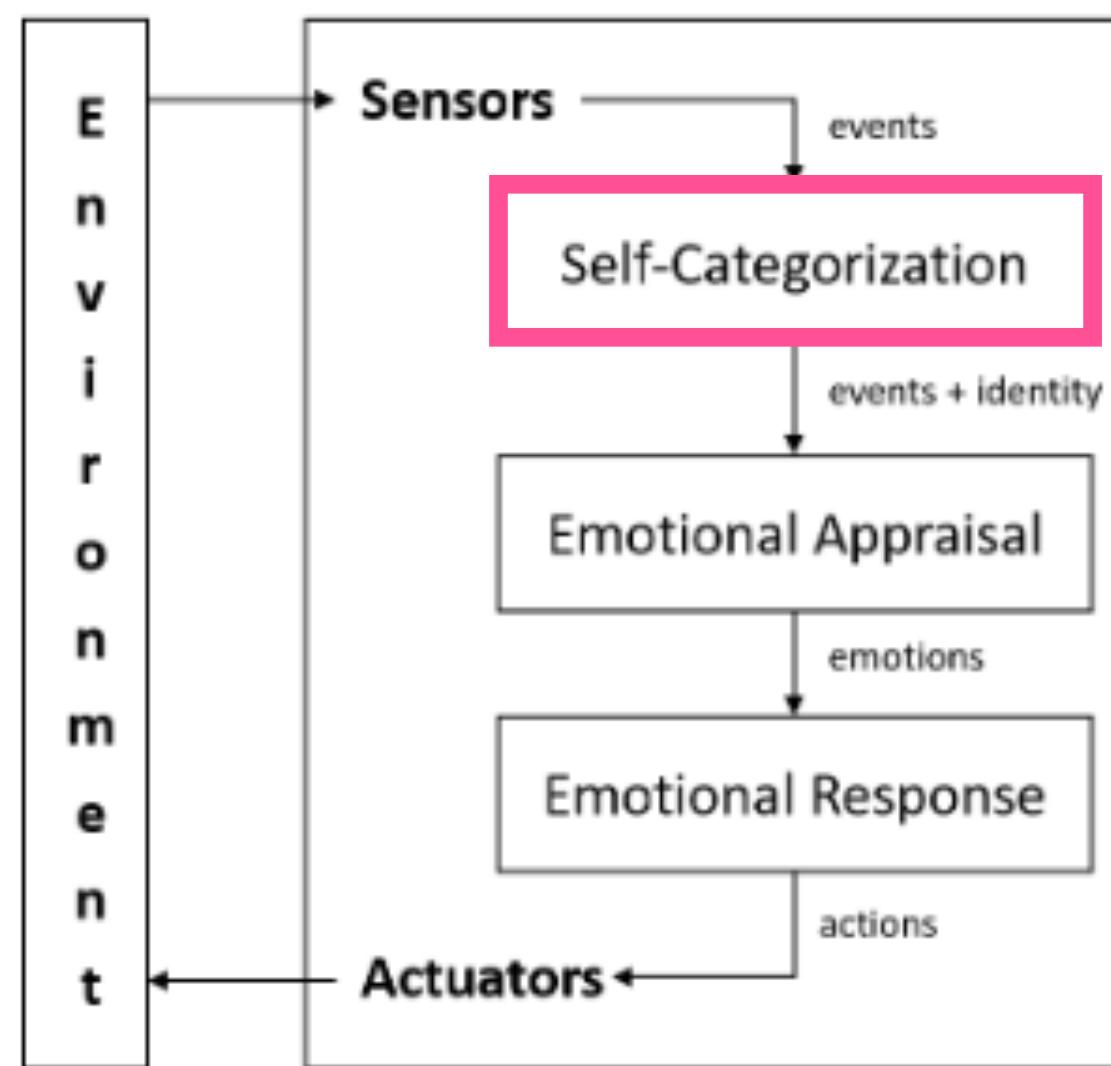
Project III - A model of Group-based Emotions

Project Goal & Research Questions

Emotional Cohesion

- Can the expression of group-based emotions by a robotic teammate increase people's identification and trust towards the team?

A model of Group-based Emotions



Algorithm 2 Group-based emotions generation process

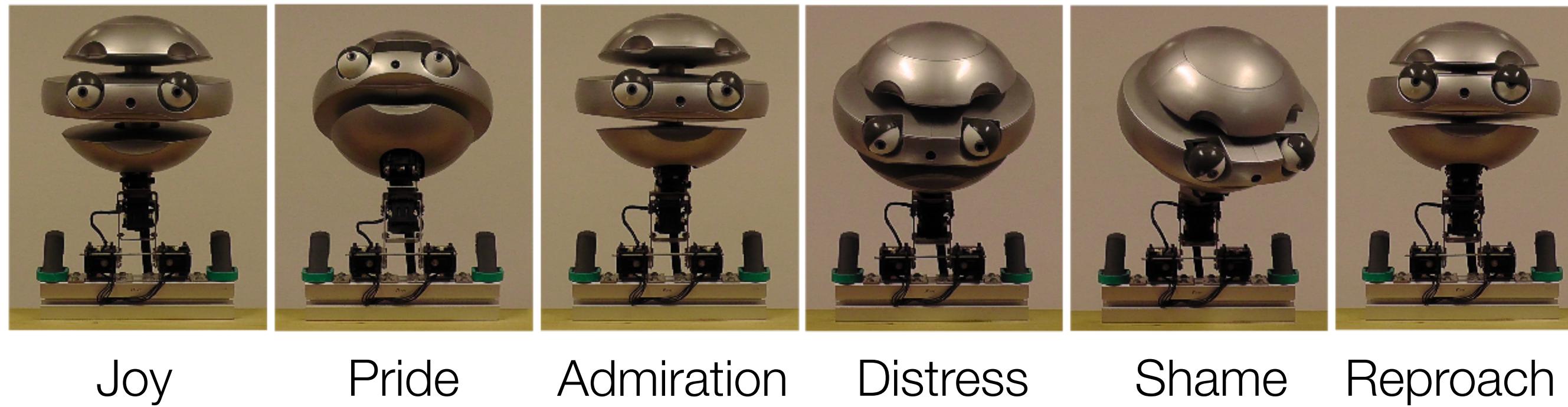
```
1: while true do
2:   self ← Robot.Name
3:   e ← Sensors.PerceiveNewEvent()
4:   SG ← ContextManager.GetSalientSocialGroups()
5:   if SG ≠ ∅ then
6:     g ← IdentityManager.SelfCategorisation(SG, self)
7:     if e.ResponsibleAgent ∈ g then
8:       e.ResponsibleAgent ← g.Name
9:       self ← g.Name
10:    AV ← Appraisal.DetermineVariables(e)
11:    E ← Appraisal.GenerateEmotions(AV, self)
12:    se ← StrongestEmotion(E)
13:    for all c ∈ Actuators.GetEmotionChannels() do
14:      Express(se, c)
```

User Study

- 2 autonomous robots
 - 1 with group-based emotions
 - 1 with individual-based emotions
- Card game



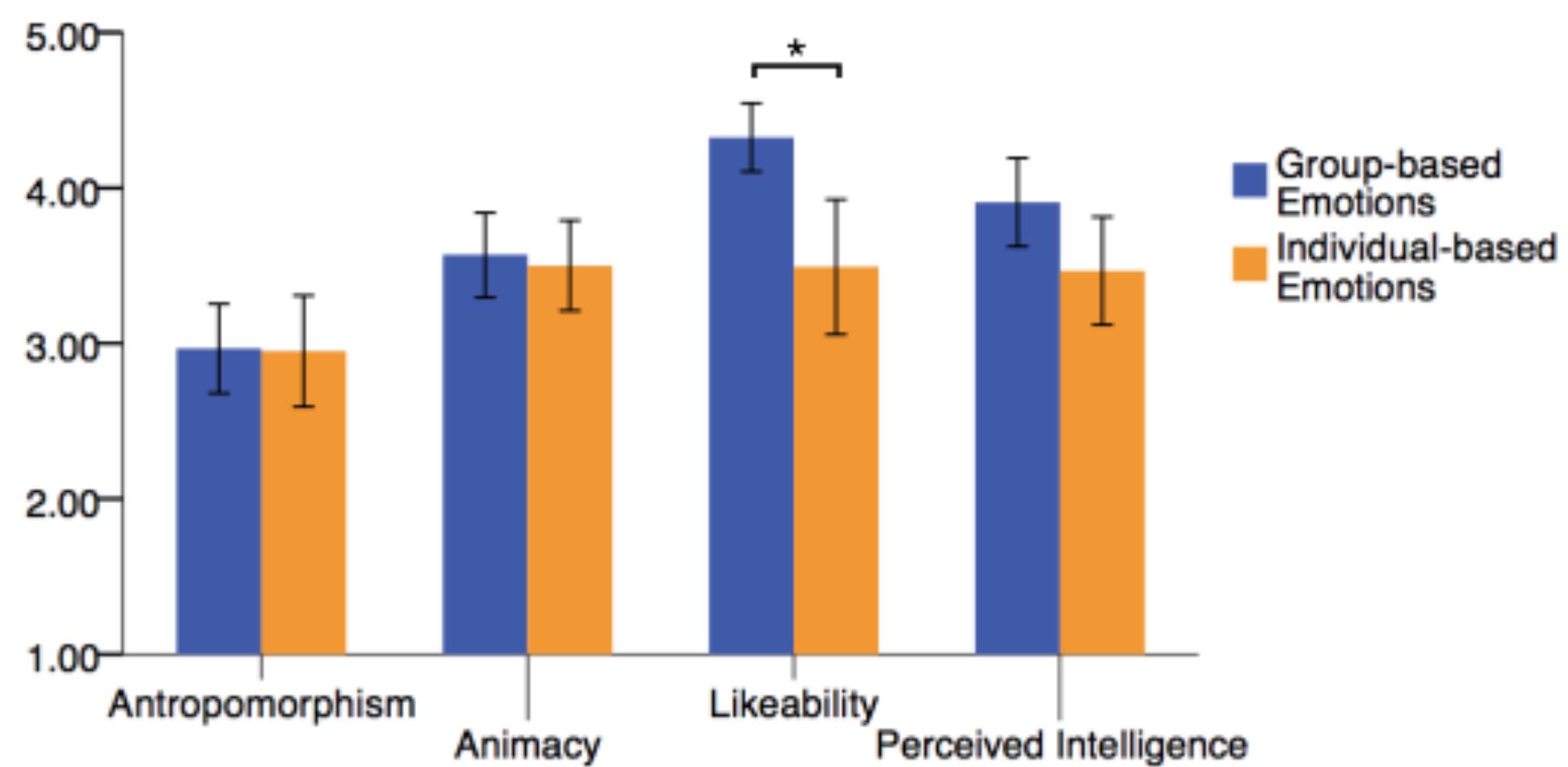
User Study - Manipulation



	Robot that expresses individual-based emotions				Robot that expresses group-based emotions			
	Admiration	Reproach	Pride	Shame	Admiration	Reproach	Pride	Shame
Partner increased score	I am impressed with your move!	—	—	—	—	—	We are the best!	—
Partner decreased score	—	With that move, I cannot win.	—	—	—	—	—	We were not so good this time...

User Study - Results

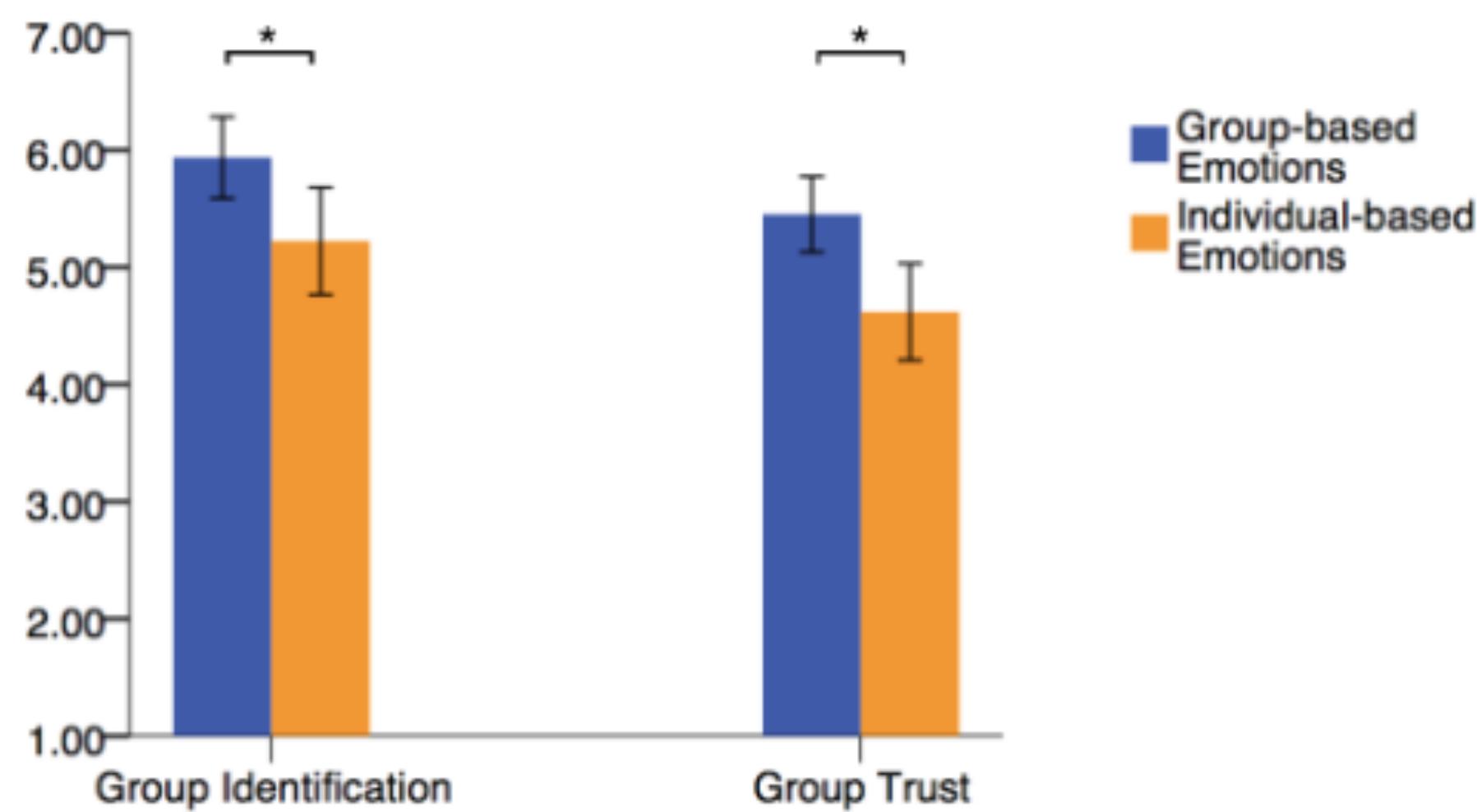
Social attributes (Godspeed)



$p=0.07$ $p=0.79$ **$p<0.01$** $p=0.80$

User Study - Results

Group measures



p=0.02

p<0.01

User Study - Take-away Message

Emotional cohesion should be considered in the design of social behaviours for robotic teammates

Other follow-up work

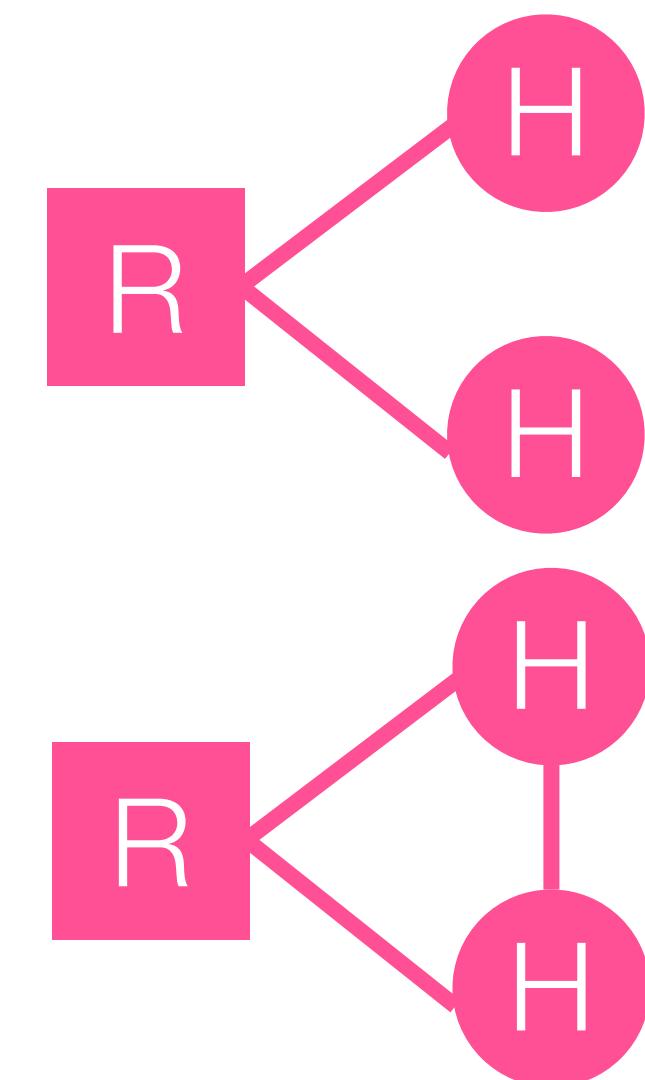
- Stereotype Content Model (warmth and competence) in HRI

Project IV - Gaze behaviours in Multi- party Settings

Project Goal & Research Questions

Structural Cohesion

- What is the degree of connectivity that a robotic teammate should consider in its perceptive skills?
 - Should a robotic teammate perceive communicative acts only towards itself?
 - Or should it also perceive communicative acts between other pairs of team members?



Project Goal & Research Questions

Structural Cohesion

- In a silent coordination task...
- Are the *gaze behaviours* of a robotic teammate able to *enhance the coordination and fluency* of its human-robot team?

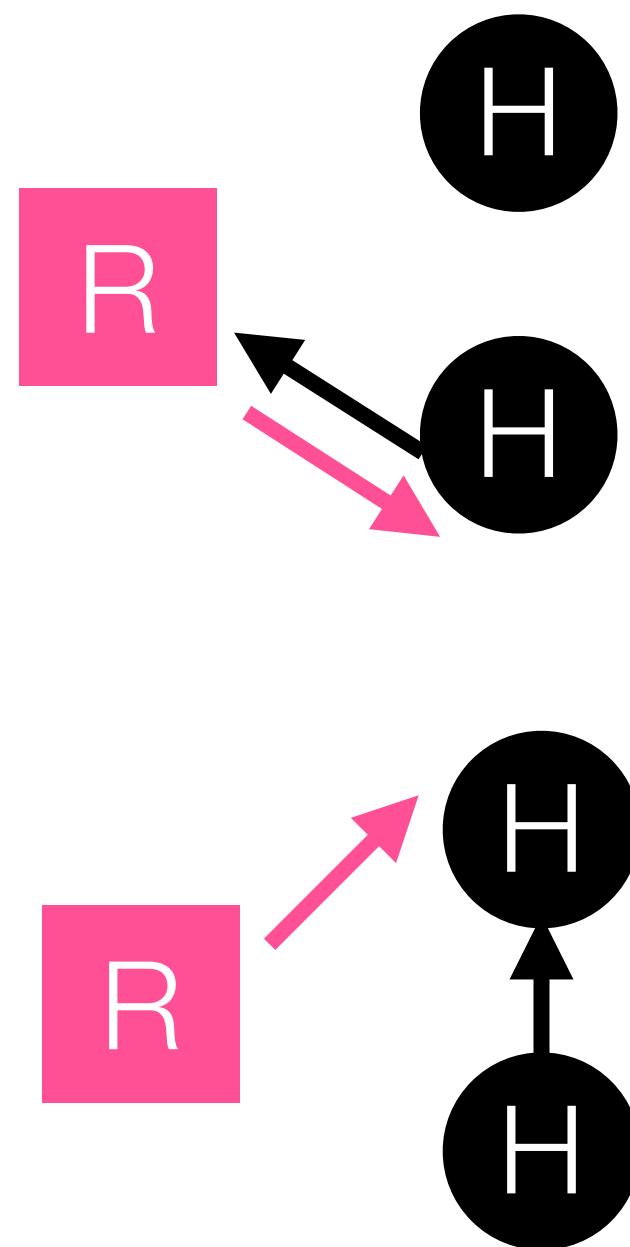
Gaze Behaviour in a Multi-party setting

Attentive Gaze

Responding Gaze

Gaze Behaviour in a Multi-party setting

Attentive Gaze



Responding Gaze

- If the teammate X looks at the *Robot*, the robot will return the gaze so that “eyes would meet” (*attempt to establish mutual gaze*).
- If the new gaze target of a teammate X is $Y \neq \text{Robot}$, it gazes at target Y (*attempt to establish joint attention*).

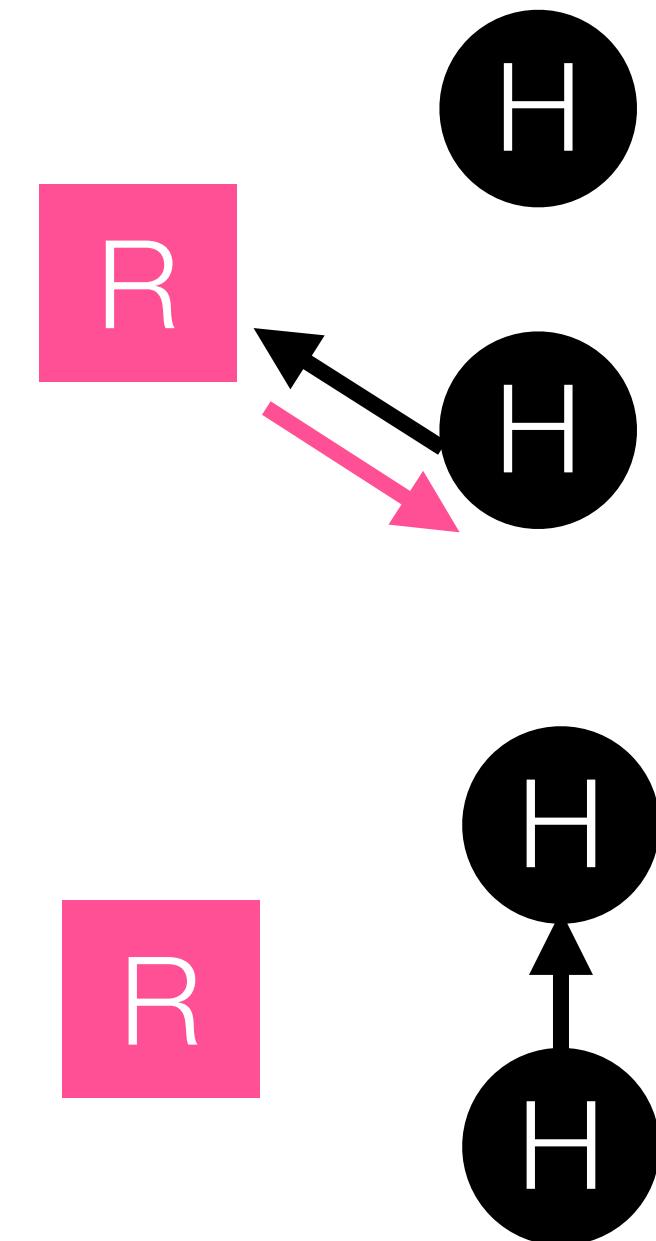
Gaze Behaviour in a Multi-party setting

Attentive Gaze

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Responding Gaze

- If the teammate X looks at the *Robot*, the robot will return the gaze so that “eyes would meet” (*attempt to establish mutual gaze*).
- If the new gaze target of a teammate X is $Y \neq Robot$, it gazes back at target *Screen*.



Gaze Behaviour in a Multi-party setting

Attentive Gaze



Responding Gaze



Video recorded excerpts of interaction

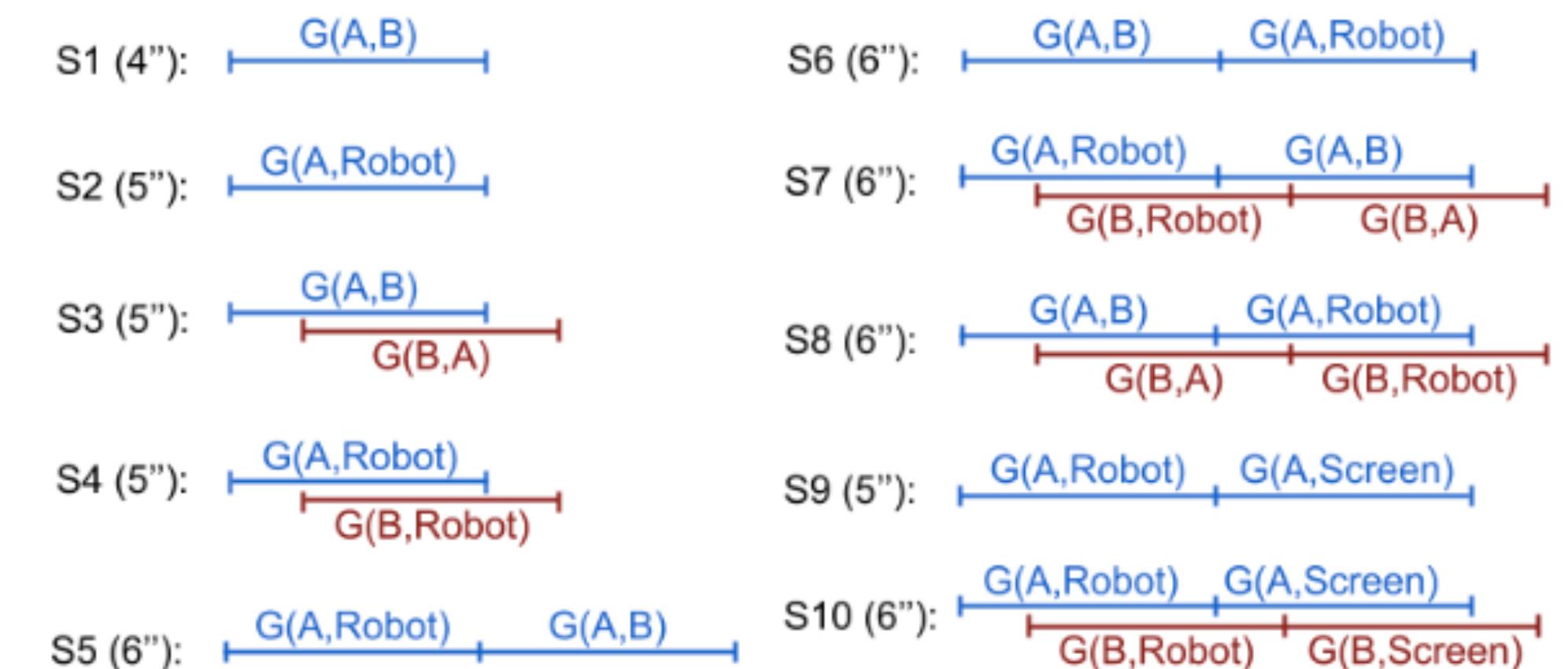
- 10 scripted interactions for human behaviour

- 3 conditions for the robot behaviour

- Robot performing Responding Gazes (RG)

- Robot performing Attentive Gazes (AG)

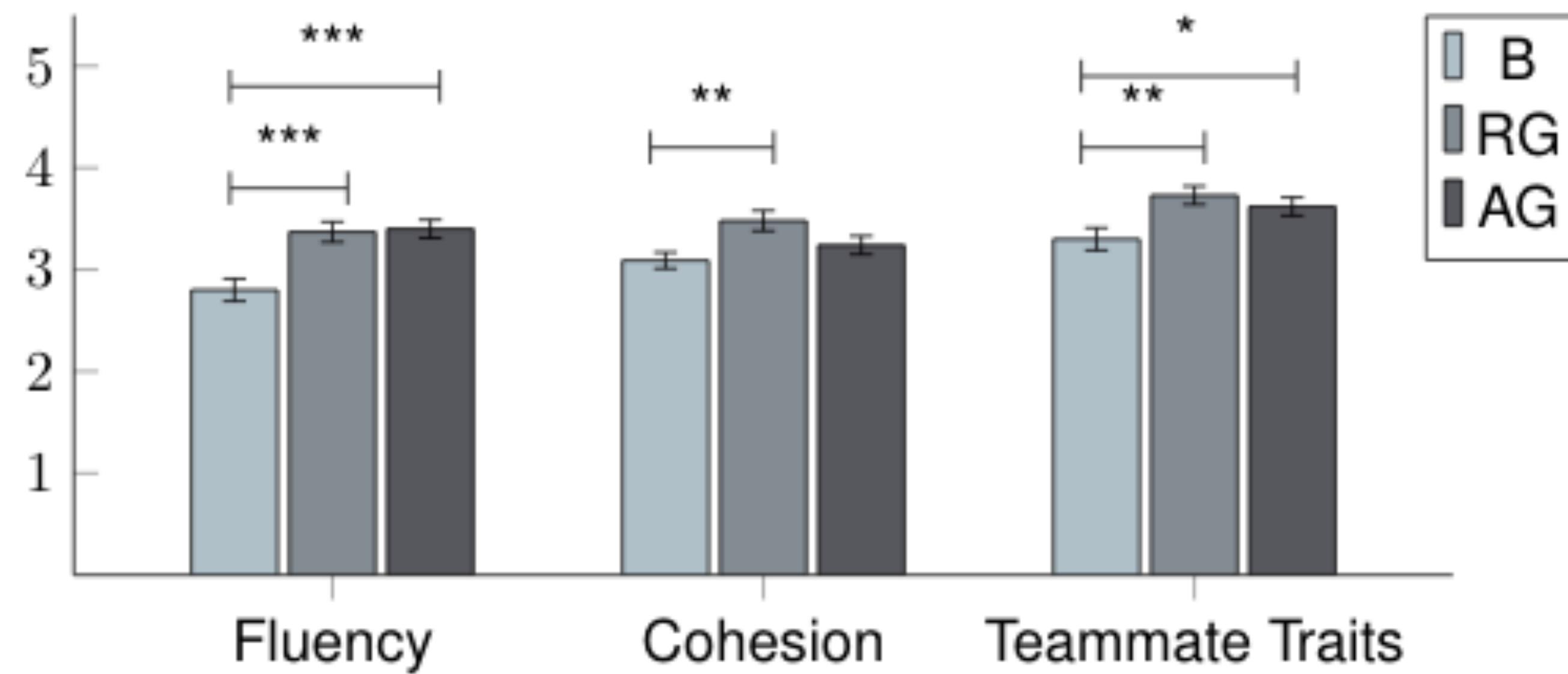
- Robot does not react to perceptions (Baseline)



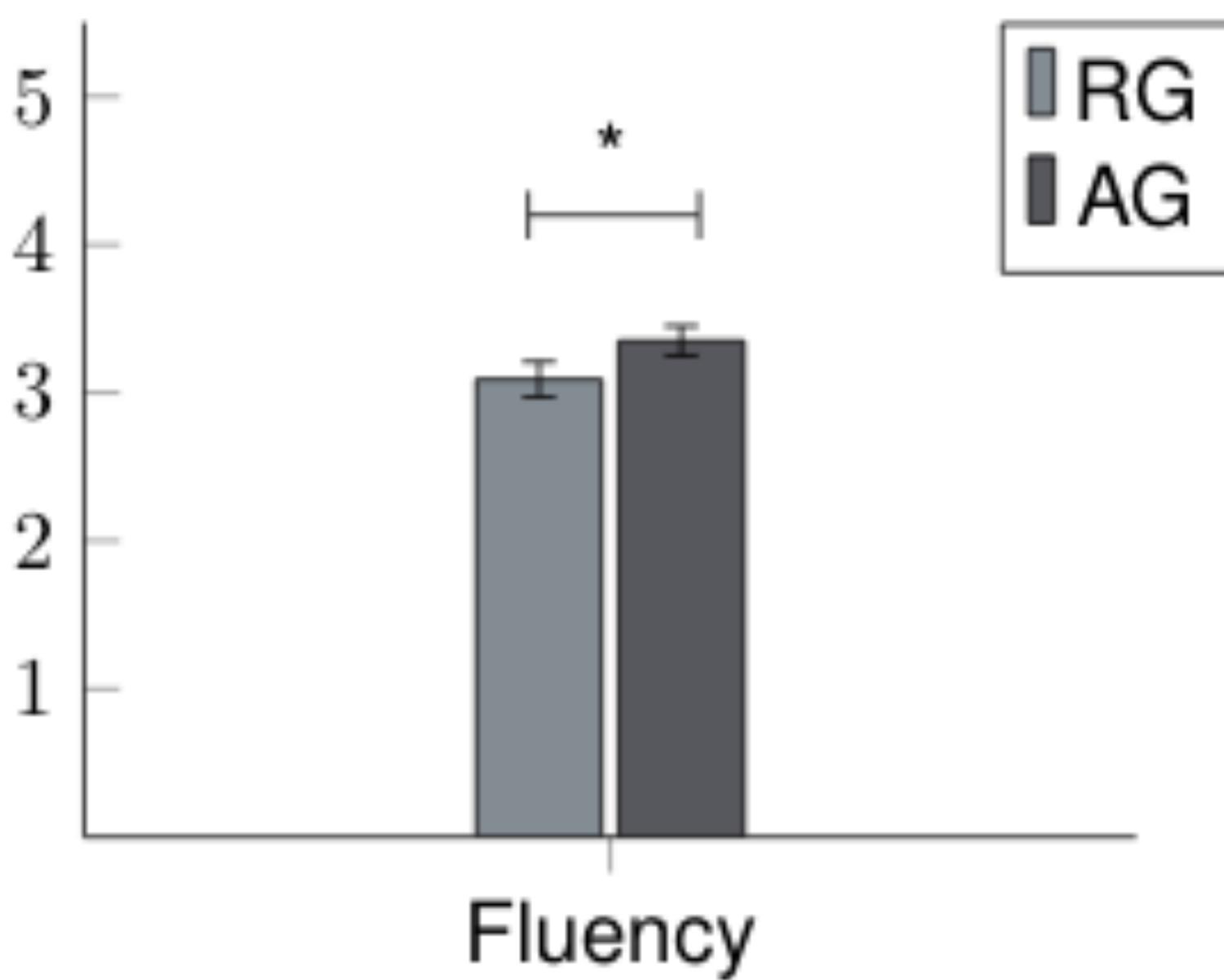
User Study

- (3 x 10) 30 small videos [4-6] seconds
- AMT third-person evaluation
- Gaze condition in a between-subjects

Results - Grouping the 10 scenes



Results - Scenes with G(A,B)



User Study - Take-away Message

The non-verbal communication structure assumed by a robotic teammate in a multi-party silent task can affect the perception of teamwork.

Conclusions

Contributions

How can we endow a robotic teammate with social capabilities to improve the cohesive alliance in a multi-party setting with humans?

Contributions

1. Computational mechanisms to develop autonomous social behaviour for robotic teammates in multi-party settings

Contributions

1. Computational mechanisms to develop autonomous social behaviour for robotic teammates in multi-party settings

2. Evaluation of people's behaviours and perceptions towards a mixed human-robot group

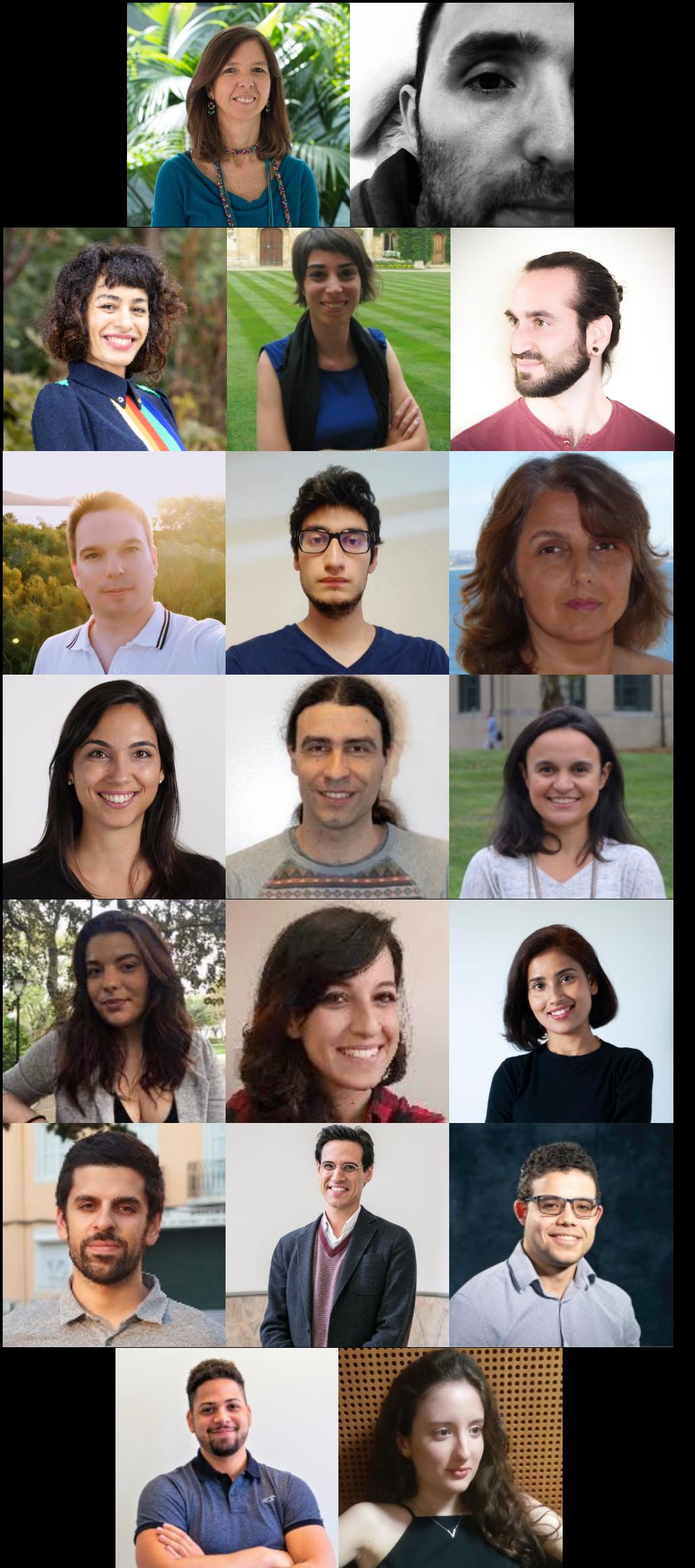
Contributions

1. Computational mechanisms to develop autonomous social behaviour for robotic teammates in multi-party settings
2. Evaluation of people's behaviours and perceptions towards a mixed human-robot group
3. Understanding relevant group processes in mixed-groups of humans and robots

Future directions for H-R Teamwork in Multi-party

- *Different group sizes and human-robot configurations*
- *Different embodiments or anthropomorphic features*
- *Autonomous perception of group patterns*

Special thanks to my collaborators:



Ana Paiva (Advisor)

Francisco S. Melo (Co-advisor)

Patrícia Alves-Oliveira

Sofia Petisca

Tiago Ribeiro

Samuel Mascarenhas

Samuel Gomes

Patrícia Arriaga

Iolanda Leite

Rui Prada

Joana Campos

Raquel Oliveira

Silvia Tulli

Shruti Chandra

Fernando P. Santos

Francisco C. Santos

Julien Charles-Nicolas

Justin Gally

Diana Lopes

Thank you all!

I am on the job market!



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