Group Intelligence on Social Robots

Filipa Correia

PhD Thesis Proposal - January 2020

Jury members:
Prof. Malte Jung, Cornell University
Prof. Hugo Nicolau, University of Lisbon (President)
Prof. Ana Paiva, University of Lisbon (Advisor)
Prof. Francisco S. Melo, University of Lisbon (Co-advisor)

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Outline

1. Motivation
2. Related Work
3. Membership Preferences and Team Formation
4. Pro-sociality
5. A model of Group-based Emotions
6. Communication Network
7. Conclusions

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1. Motivation

Motivation

- Multi-party settings in HRI

Motivation

- Multi-party settings in HRI
  - Human-robot mixed groups

Motivation

- Multi-party settings in HRI
    - Human-robot mixed groups
    - Robotic teammates

What is a Group?

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

- Interactions
- Goals
- Interdependence
- Structure
- Cohesion

Forsyth, D. R. (1990). **Group dynamics.**

What is a Team?

Team - “unified, cohesive group”

- Coordinated interactions
- Common goals
- Strong interdependence
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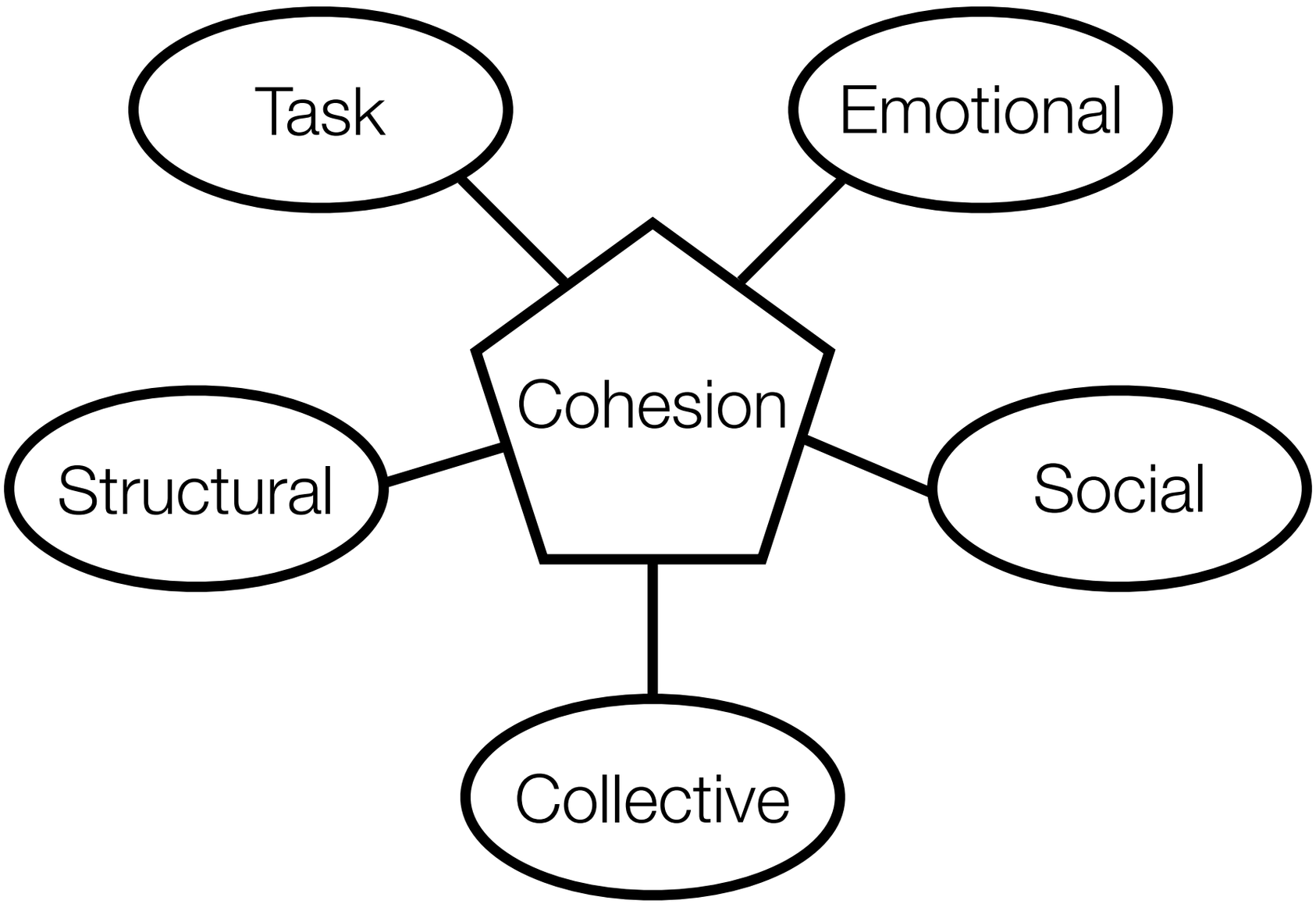
Research Problem

How can we endow a social robot with the ability to improve the cohesive alliance in a team setting with humans?

What is Cohesion?



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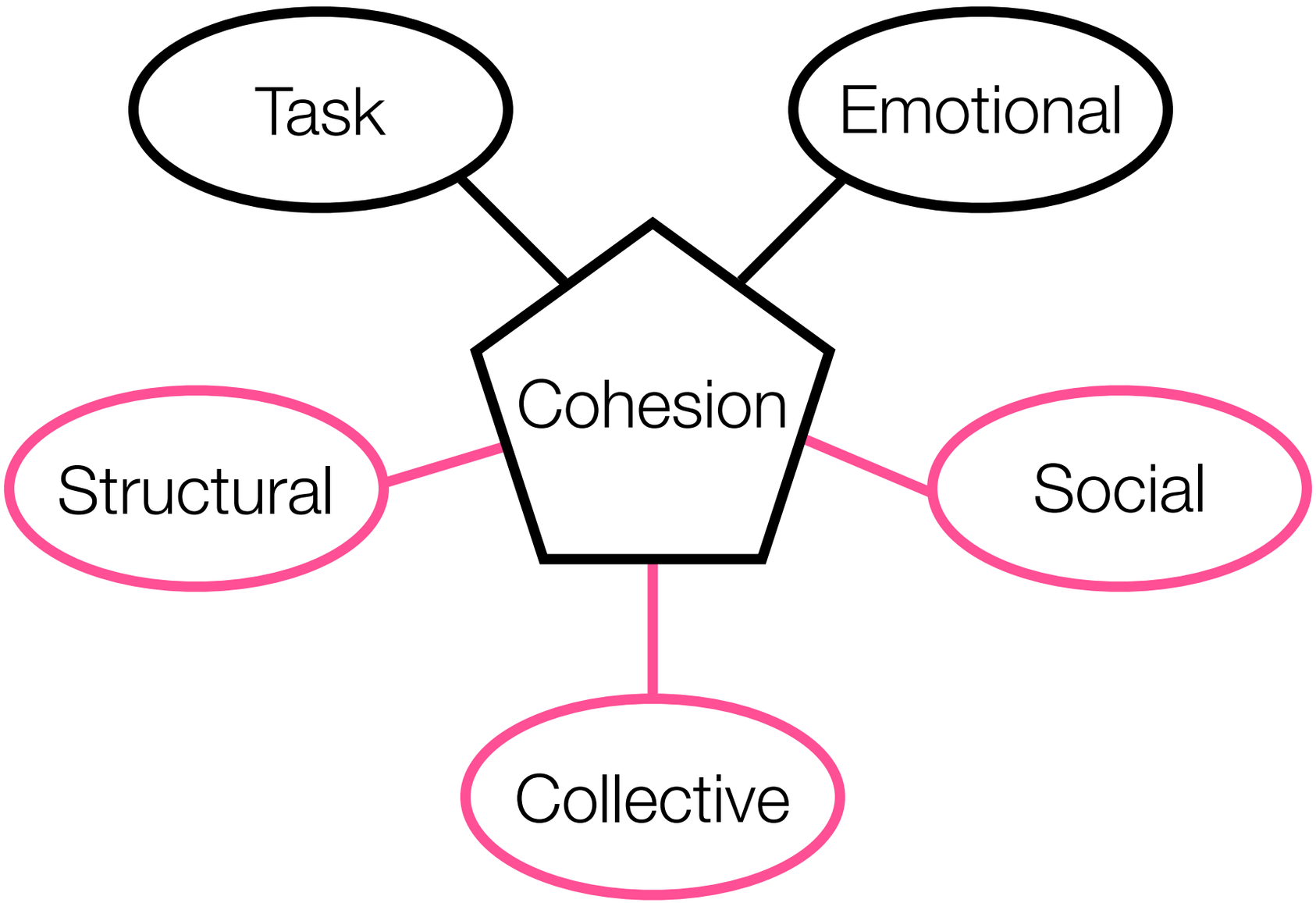

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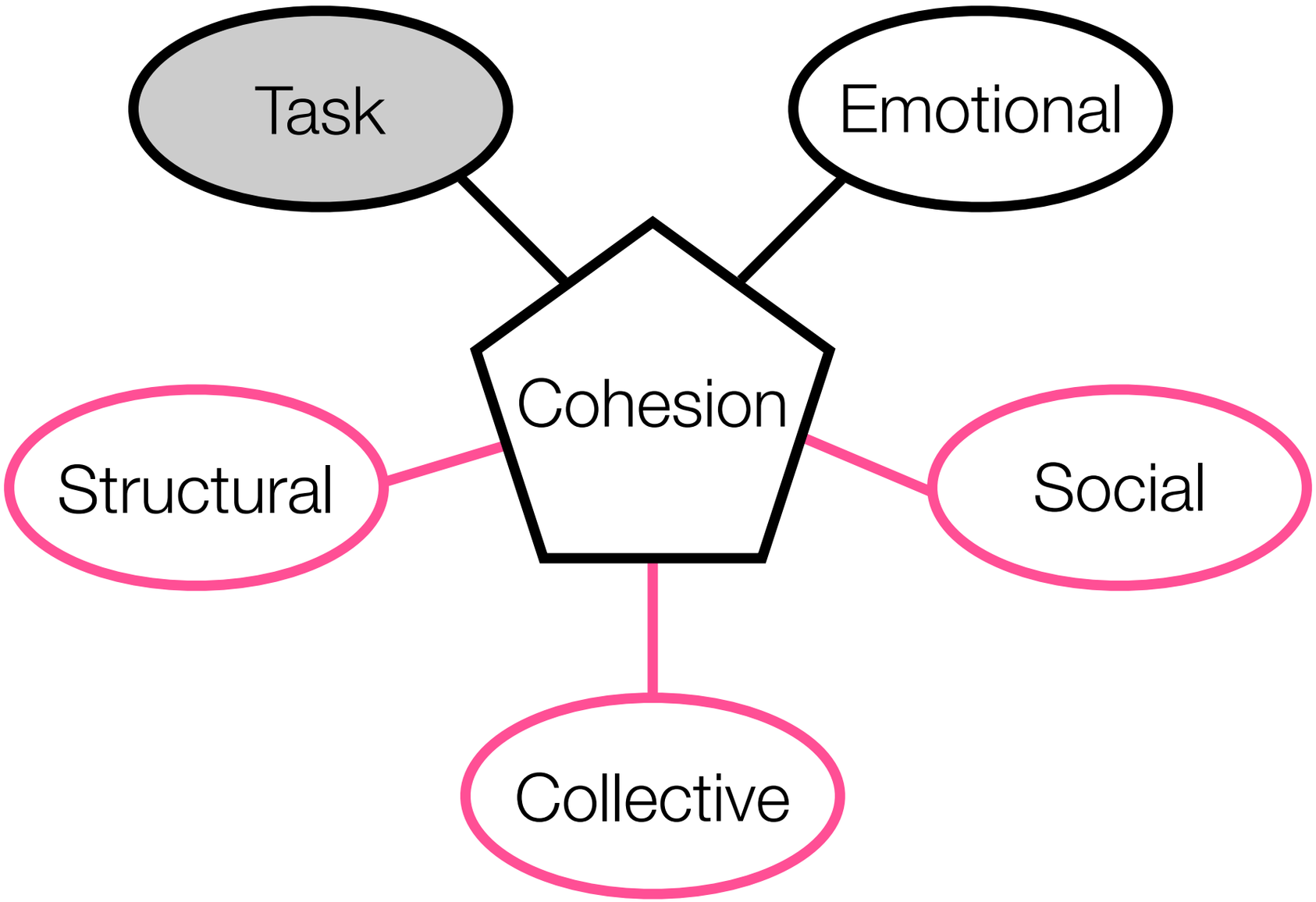

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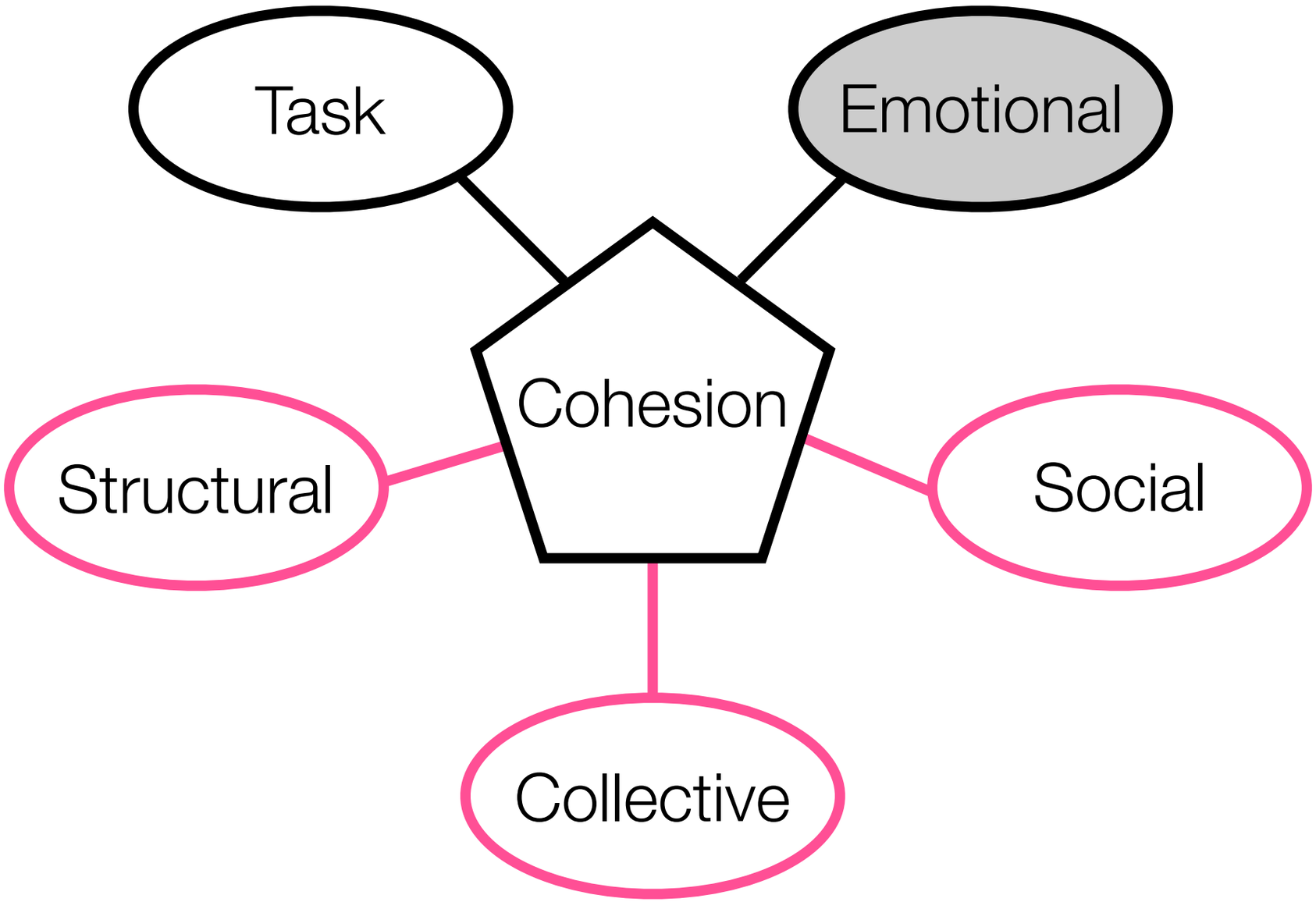

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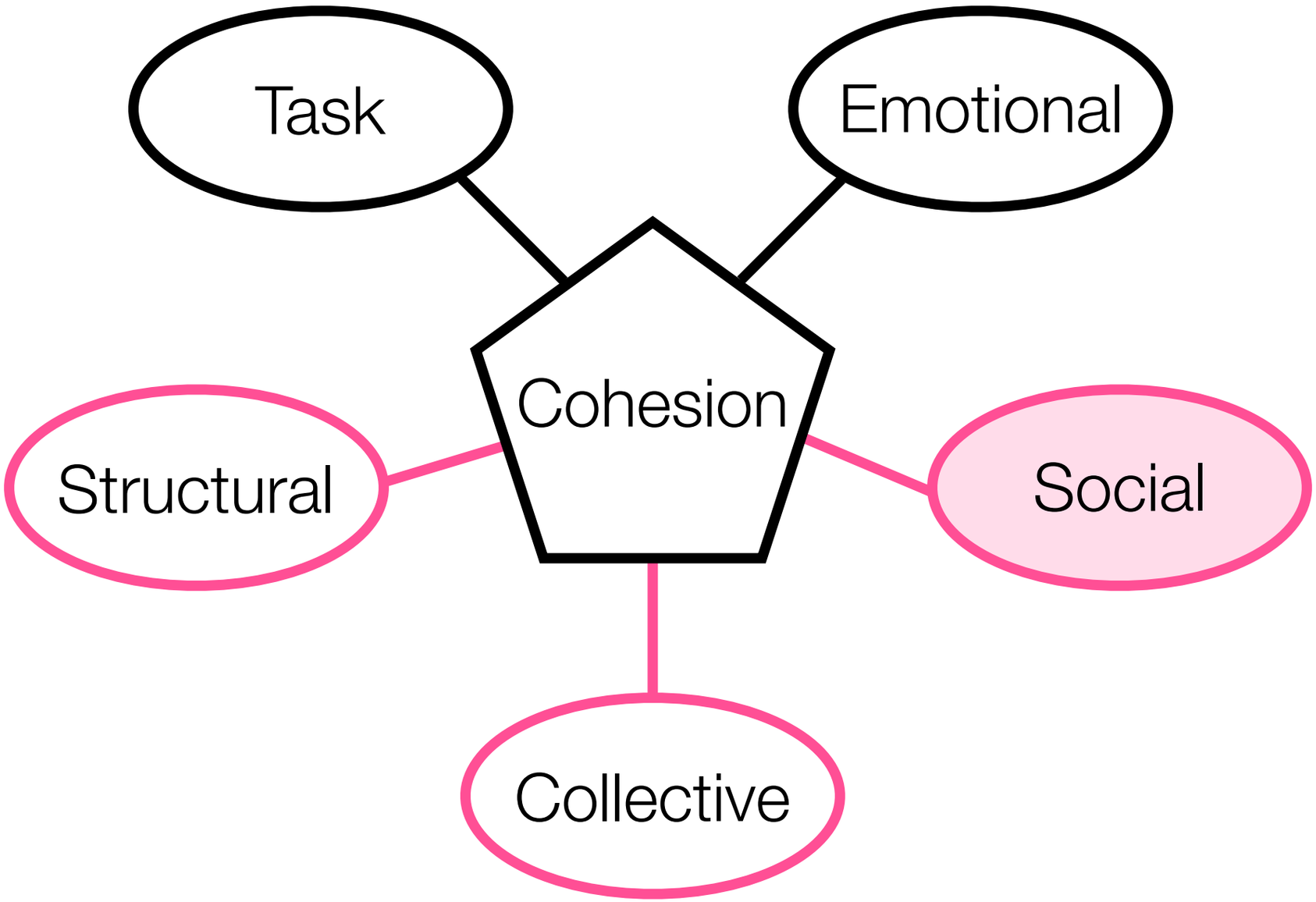

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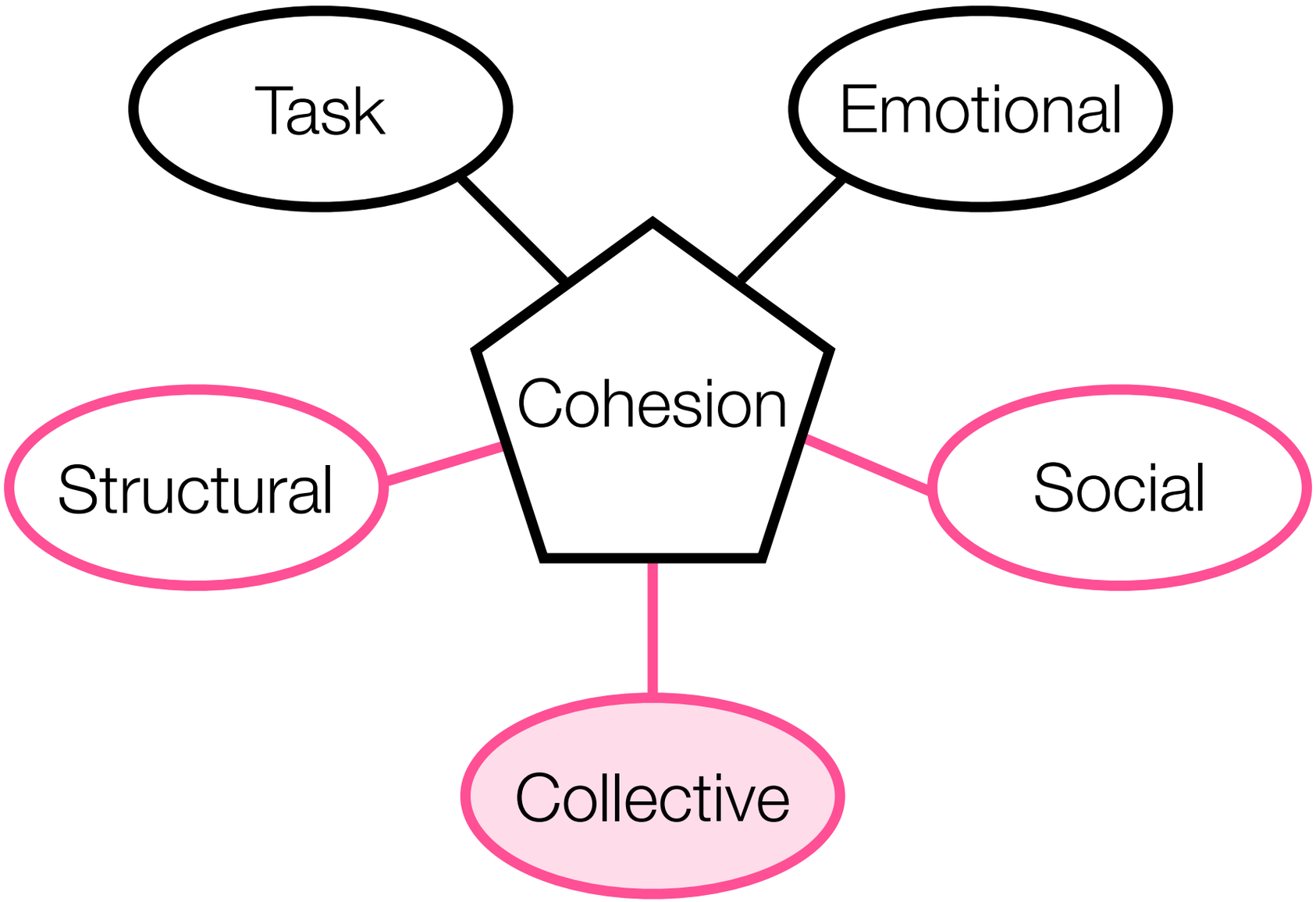

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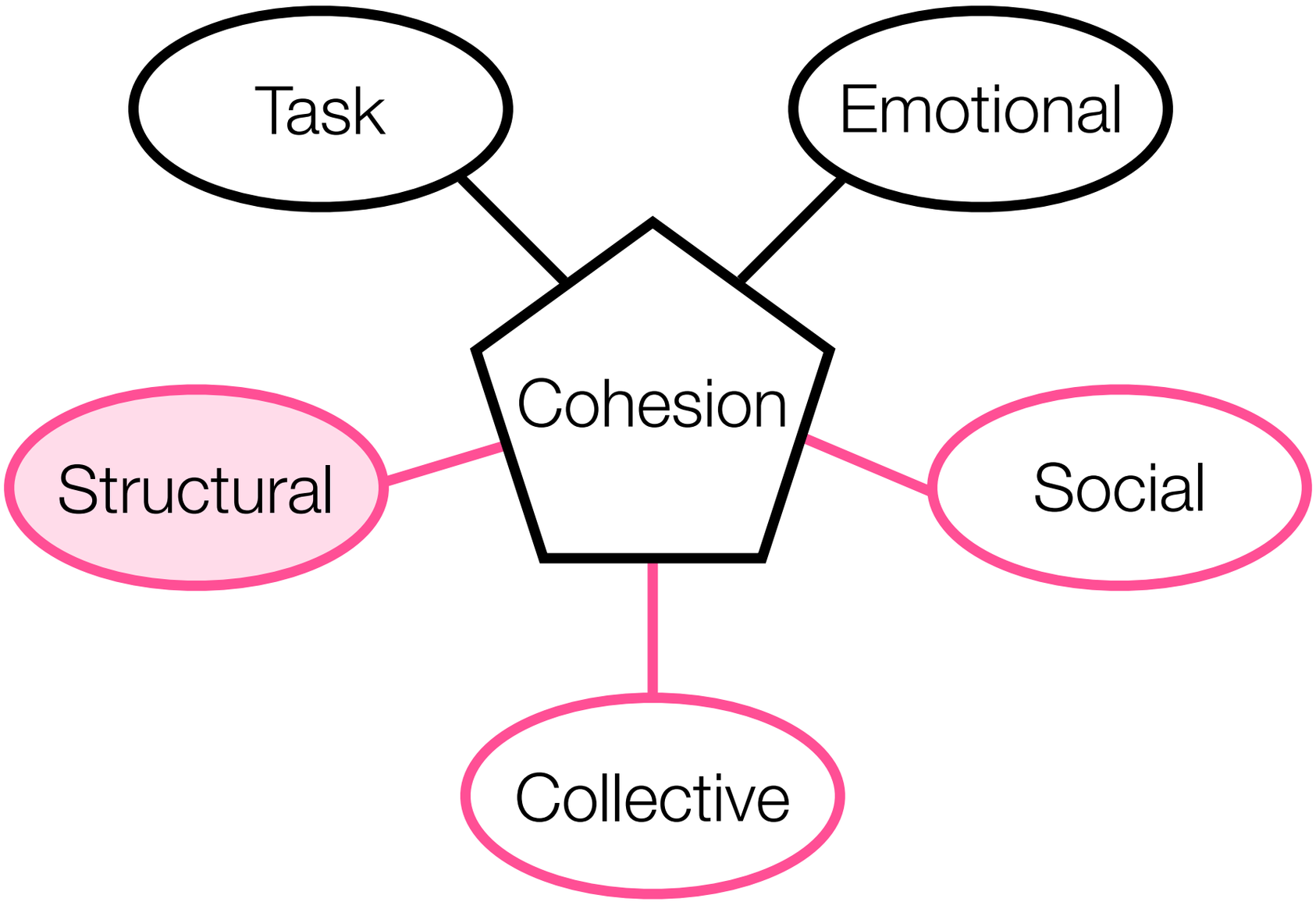

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Research Goals

1. Evaluate the impact of the robot's social behaviours on the social cohesion → Membership Preferences & Team Formation

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2. Evaluate the impact of the team's outcome on the collective cohesion → Pro-sociality

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3. Develop computational mechanisms for the robotic teammate to improve collective cohesion → A model of Group-based Emotions

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2. Evaluate the impact of the team's outcome on the collective cohesion → Pro-sociality

3. Develop computational mechanisms for the robotic teammate to improve collective cohesion → A model of Group-based Emotions

4. Develop computational mechanisms for the robotic teammate to perceive the structural cohesion → Communication Network

2. Related Work

Related Work

Group Phenomena	Group Identity	Groups of Robots	Group Behaviour
• Chang et al. (2012)	• Eyssel & Kuchenbrandt (2012)	• Admoni et al. (2013)	• Leite et al. (2015)
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Expected Contributions

Membership Preferences & Team Formation

Pro-sociality

A model of Group-based Emotions

Communication Network

Expected Contributions

Group Identity

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Expected Contributions

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Group Behaviour

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3. Membership Preferences & Team Formation

Project Goal & Research Questions

1. Evaluate the impact of the robot's social behaviours on the social cohesion → Membership Preferences & Team Formation

Project Goal & Research Questions

1. Evaluate the impact of the robot's social behaviours on the social cohesion → Membership Preferences & Team Formation

   - How do relationships and attractions develop towards robotic teammates?

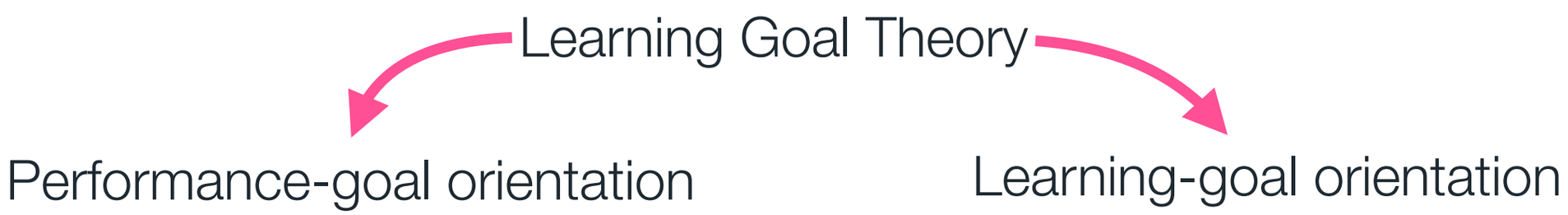
   - What traits do people prefer on robotic teammates?

Goal Orientation Theory

Learning Goal Theory

C. O. Porter, “**Goal orientation: effects on backing up behavior, performance, efficacy, and commitment in teams.**”, Journal of Applied Psychology, vol. 90, no. 4, p. 811, 2005.

Goal Orientation Theory



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Goal Orientation Theory

Learning Goal Theory

Performance-goal orientation

Learning-goal orientation

Creating two characters

Competitive

Emys

Relationship-driven

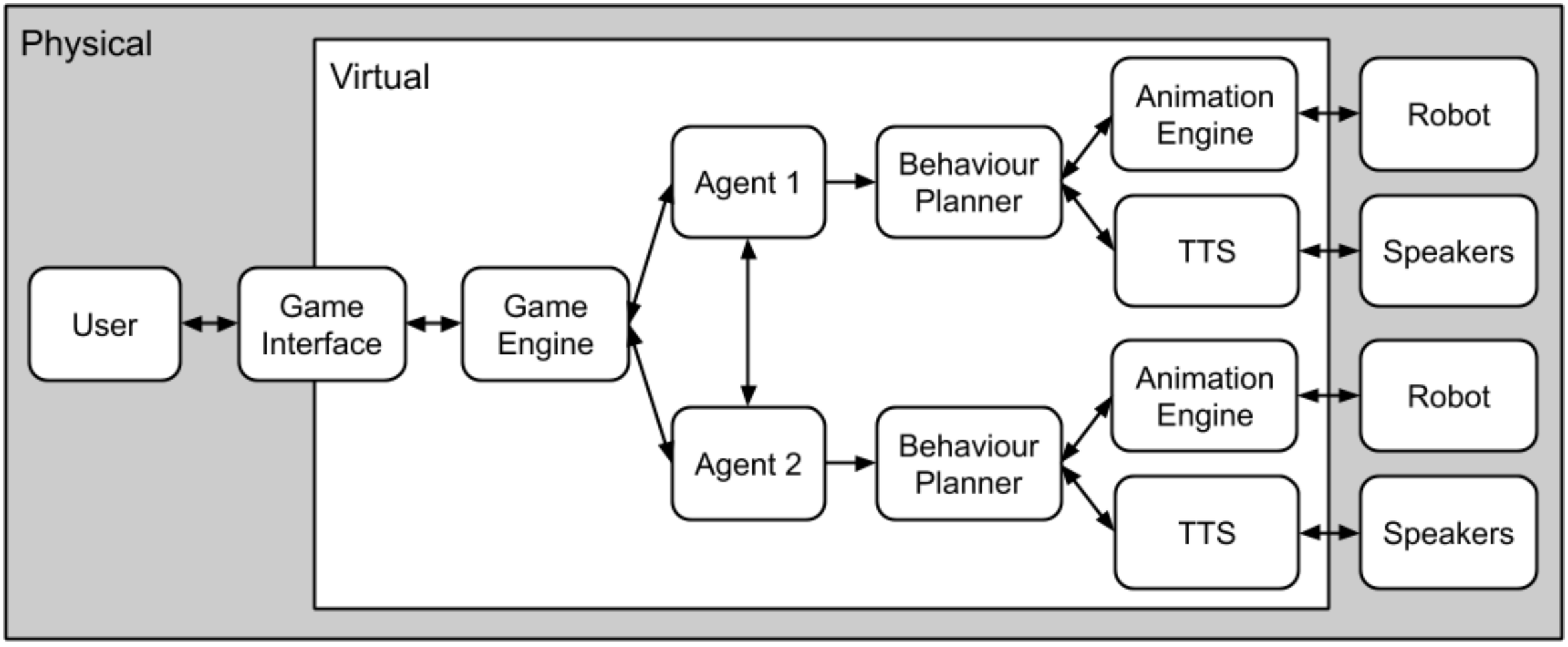
Glin

C. O. Porter, "**Goal orientation: effects on backing up behavior, performance, efficacy, and commitment in teams.**", Journal of Applied Psychology, vol. 90, no. 4, p. 811, 2005.

User Study

Which robot will people prefer to partner with?

Development of 2 interactive robots



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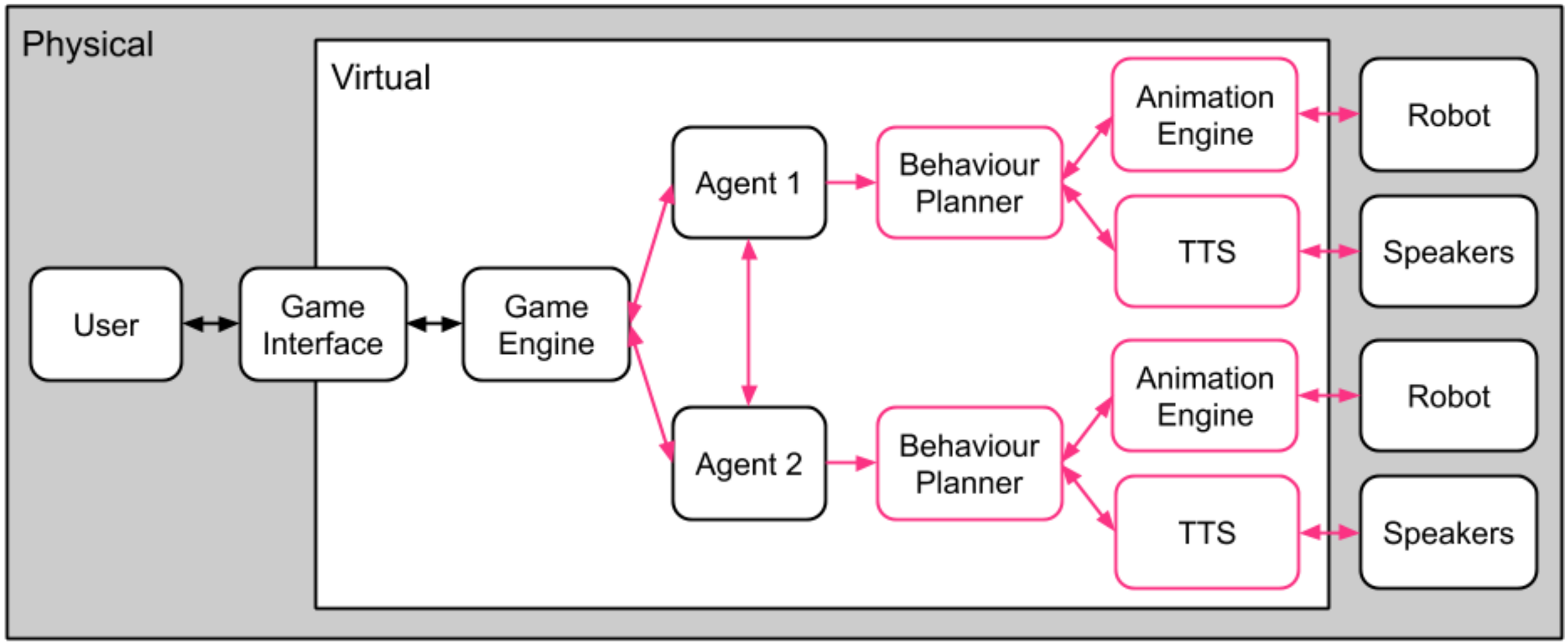
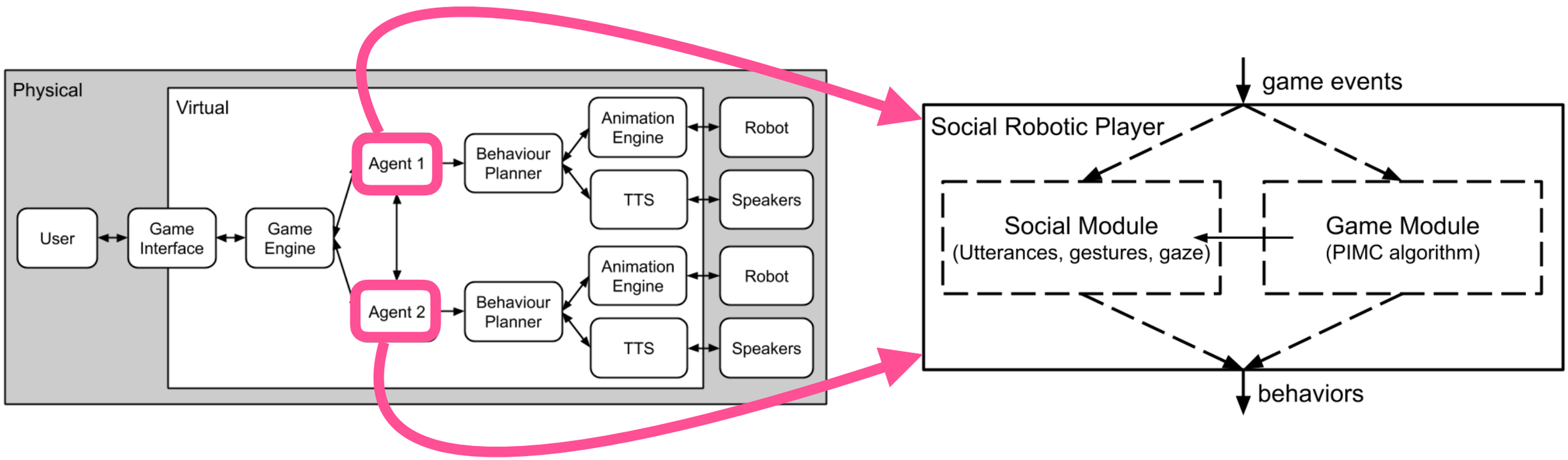
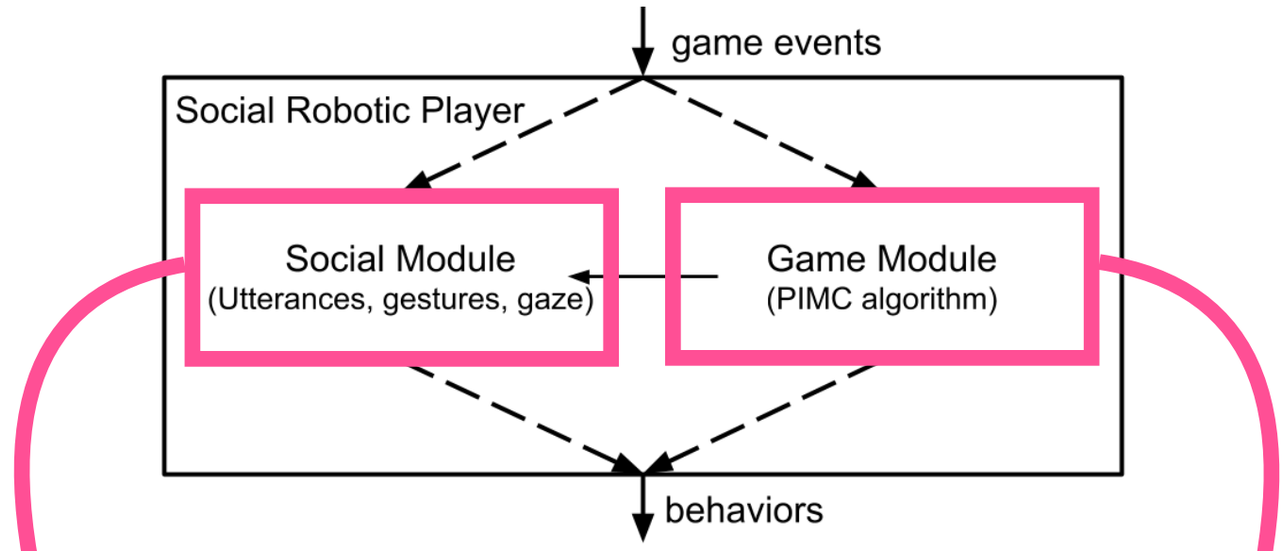


T. Ribeiro, A. Pereira, E. Di Tullio, and A. Paiva, **“The sera ecosystem: Socially expressive robotics architecture for autonomous human-robot interaction**”, in 2016 AAAI Spring Symposium Series, 2016.

Development of **each** interactive robot



Development of **each** interactive robot



FAtiMA Toolkit

Perfect Information Monte Carlo algorithm

Manipulation of the Goal Orientation

- Emotional non-verbal behaviour
- Scripted verbal behaviour

Game State	**Competitive robot (Emys)**	**Relationship-driven robot (Glin)**
End game (loss)	“This cannot continue like this! You have to play better!”	“No worries partner, next time we will do better!”
Playing	“Watch and learn how this is played.”	“I am so proud of being in your team!”

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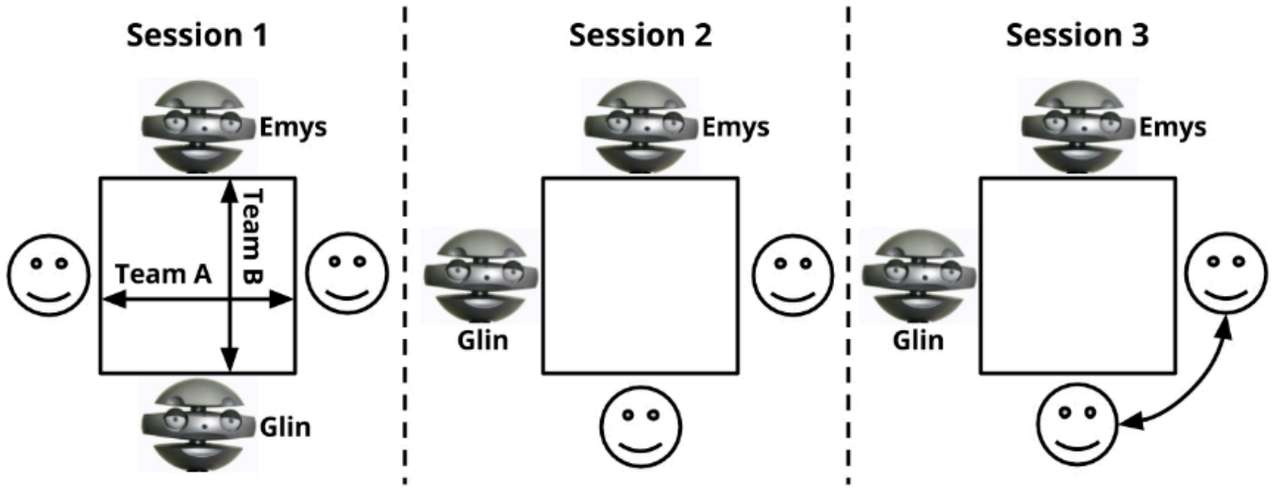
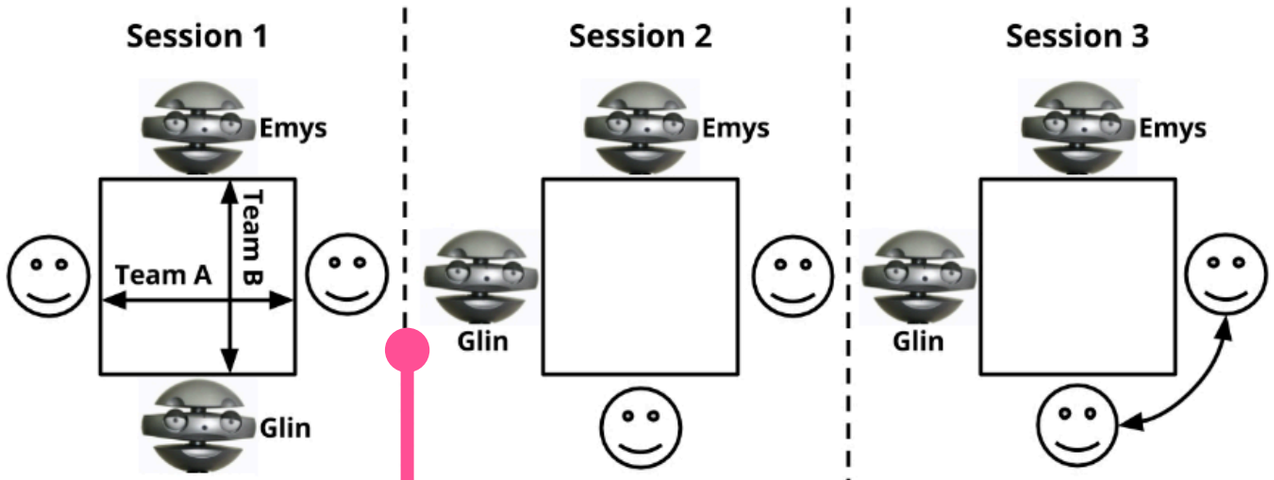
User Study

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



User Study

Which robot will people prefer to partner with?

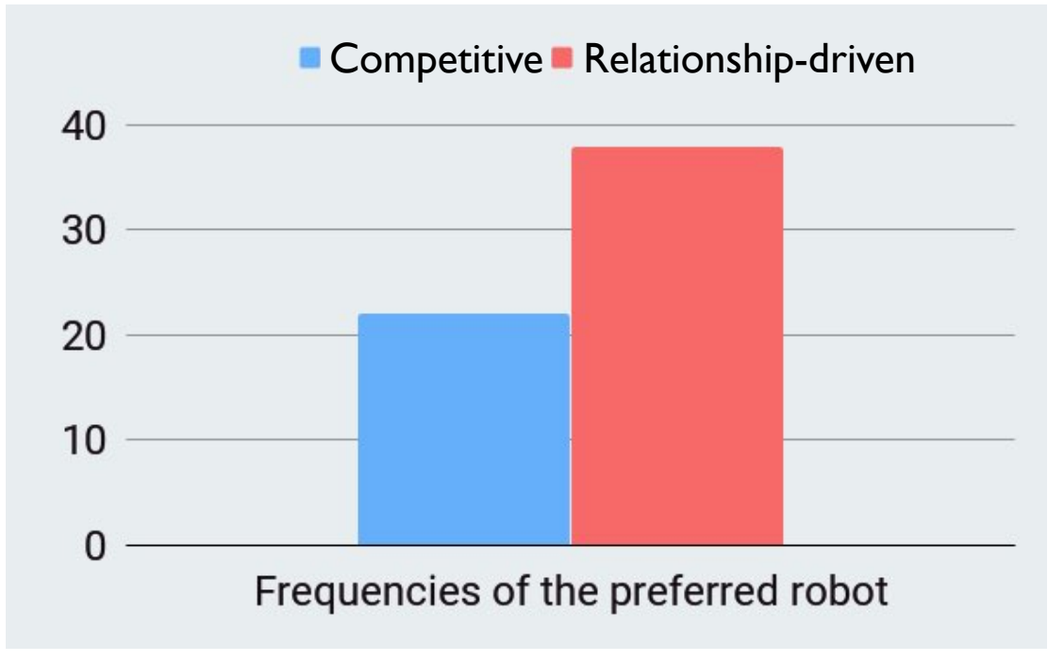


First choice of robotic partner

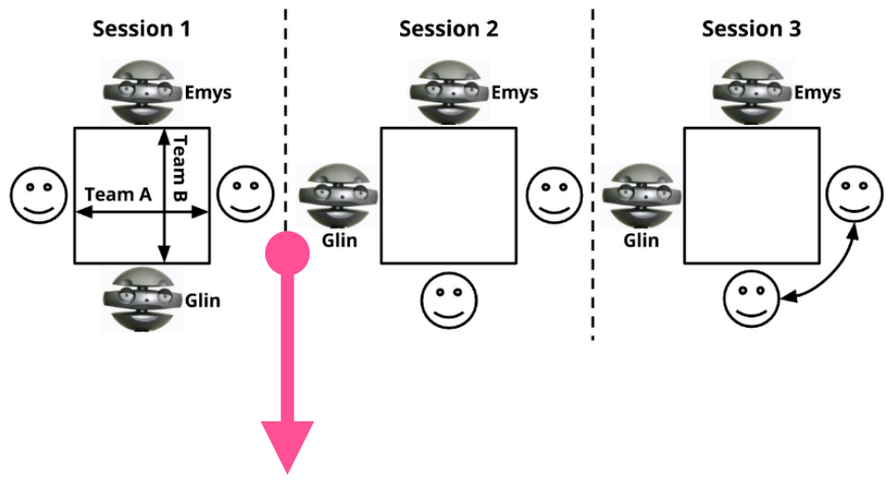
Last choice of robotic partner

User Study - Results

In the first choice…



p=0.039



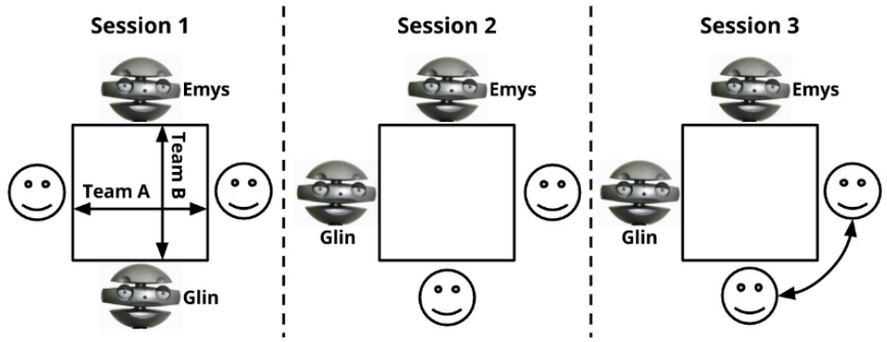
First choice of robotic partner

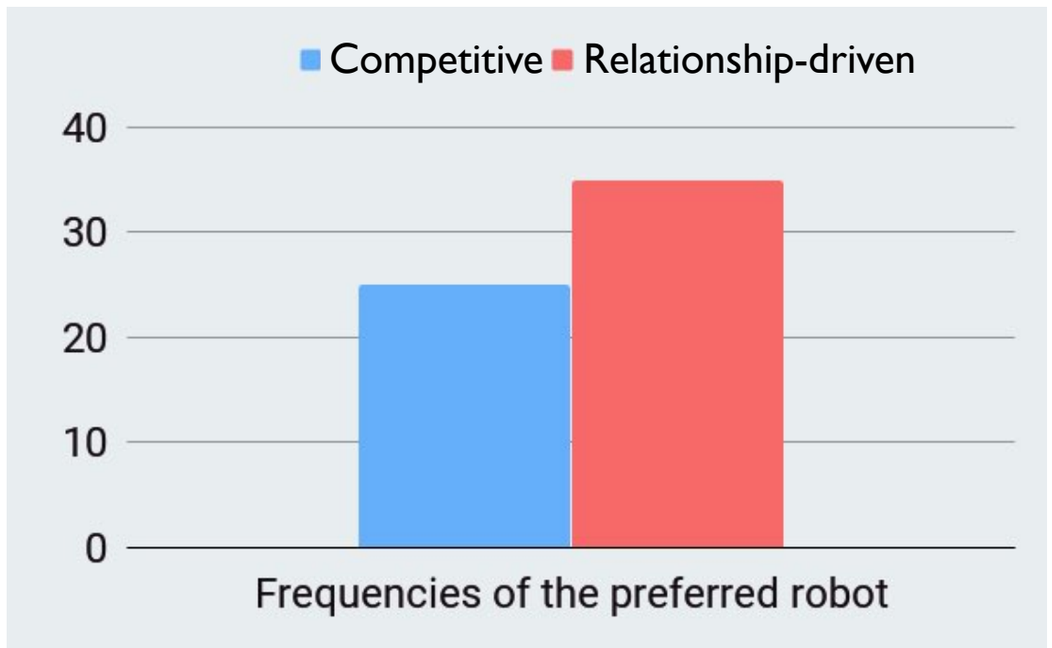
Correia, F., Petisca, S., Alves-Oliveira, P., Ribeiro, T., Melo, F. S., & Paiva, A. (2017, July). Groups of humans and robots: Understanding membership preferences and team formation. In Robotics: Science and Systems. **[RSS'17]**

Correia, F., Petisca, S., Alves-Oliveira, P., Ribeiro, T., Melo, F. S., & Paiva, A. (2019). `I Choose... YOU!'' Membership preferences in human–robot teams. Autonomous Robots, 43(2), 359-373. **[AuRo Journal]**

User Study - Results

In the last choice…





Last choice of robotic partner

p=0.197

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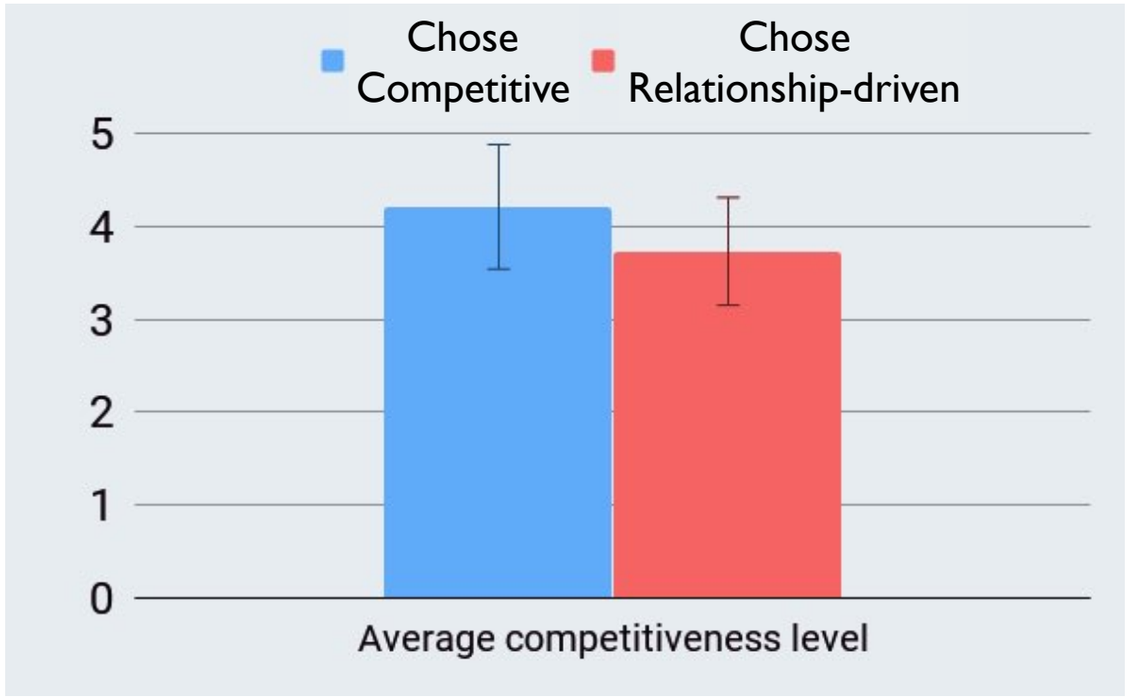
User Study - Results

Why?

- People's competitiveness was significantly different



p=0.005

Correia, F., Petisca, S., Alves-Oliveira, P., Ribeiro, T., Melo, F. S., & Paiva, A. (2017, July). Groups of humans and robots: Understanding membership preferences and team formation. In Robotics: Science and Systems. **[RSS'17]**

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User Study - Results

Why?

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

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User Study - Take-away Message

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

4. Pro-sociality

Project Goal & Research Questions

1. Evaluate the impact of the robot's social behaviours on the social cohesion → Membership Preferences & Team Formation

2. Evaluate the impact of the team's outcome on the collective cohesion → Pro-sociality

Project Goal & Research Questions

2. Evaluate the impact of the team's outcome on the collective cohesion → Pro-sociality

- 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

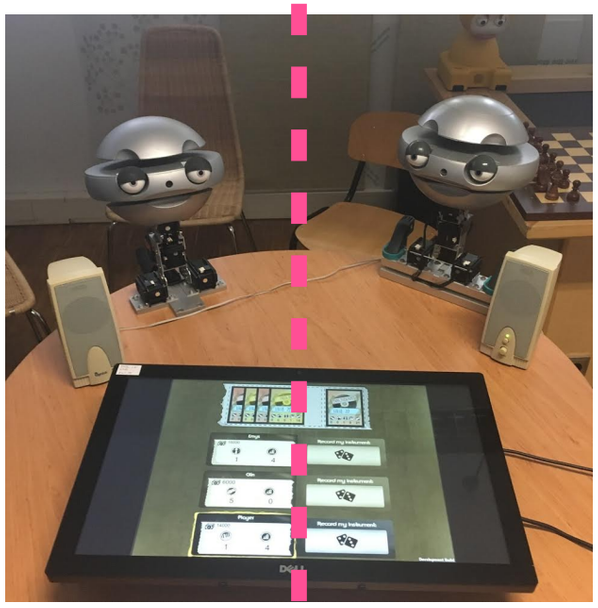
- Team of 3
  - 2 autonomous robots
  - 1 person

- Collective Risk Dilemma - For The Record
  - Common Goal - “avoid the team’s catastrophe”
  - Individual Goal - “have the highest individual score”

Experimental Design

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

Cooperator



Defector

Experimental Design

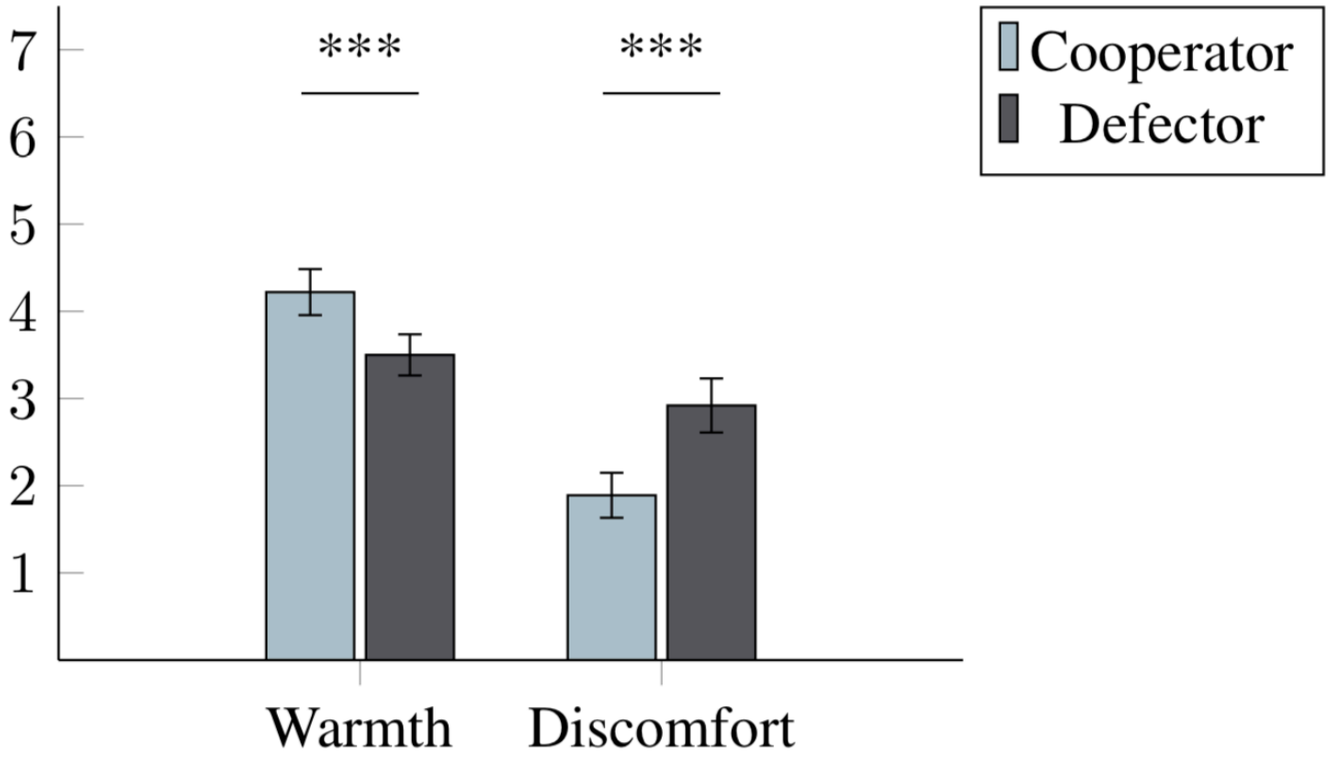
- Mixed experimental design
  - Within-subjects variable - strategy of the robots
  - Between-subjects variable - game result

Winning

Losing

User Study - Results

Social attributes of warmth and discomfort (RoSAS)

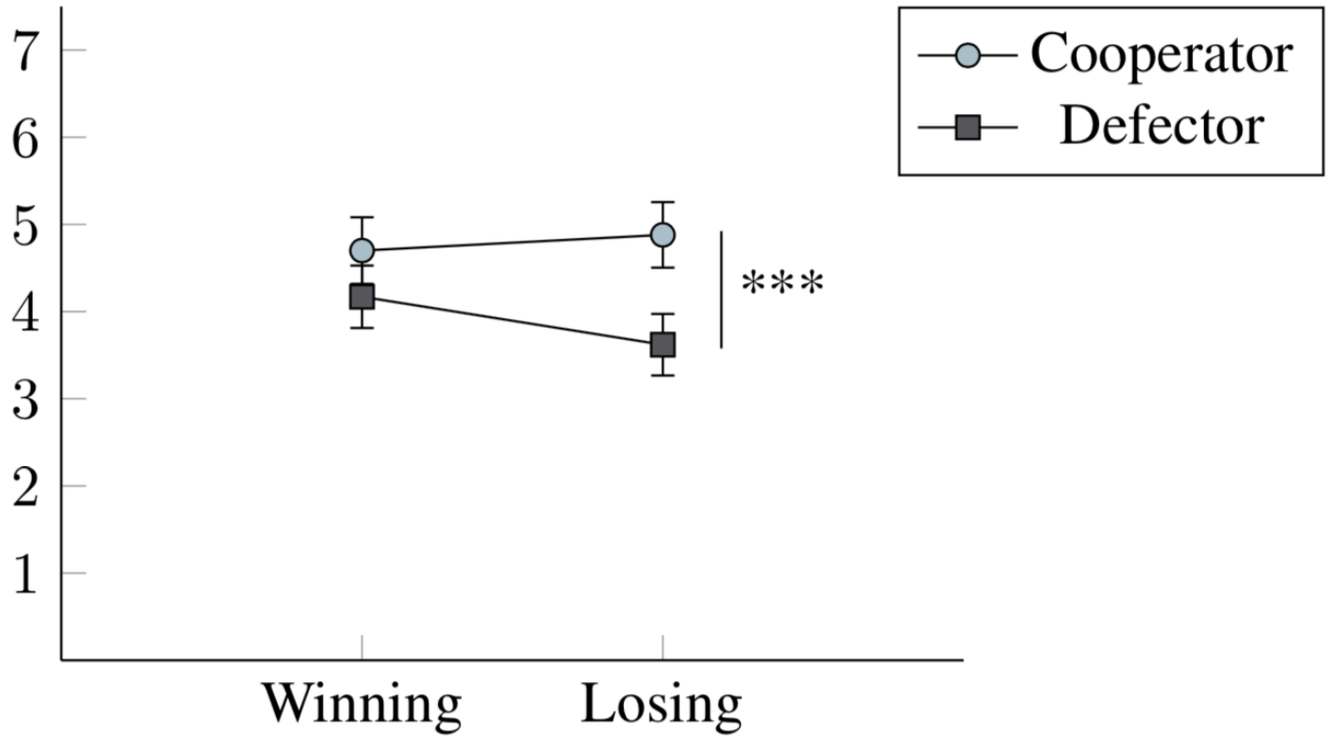


****p<0.001*

Correia, F., Mascarenhas, S. F., Gomes, S., Arriaga, P., Leite, I., Prada, R., Melo, F. S. & Paiva, A. (2019, March). Exploring prosociality in human-robot teams. In 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 143-151). IEEE. **[HRI'19]**

User Study - Results

Social attribute of competence (RoSAS)



$p = 0.047$

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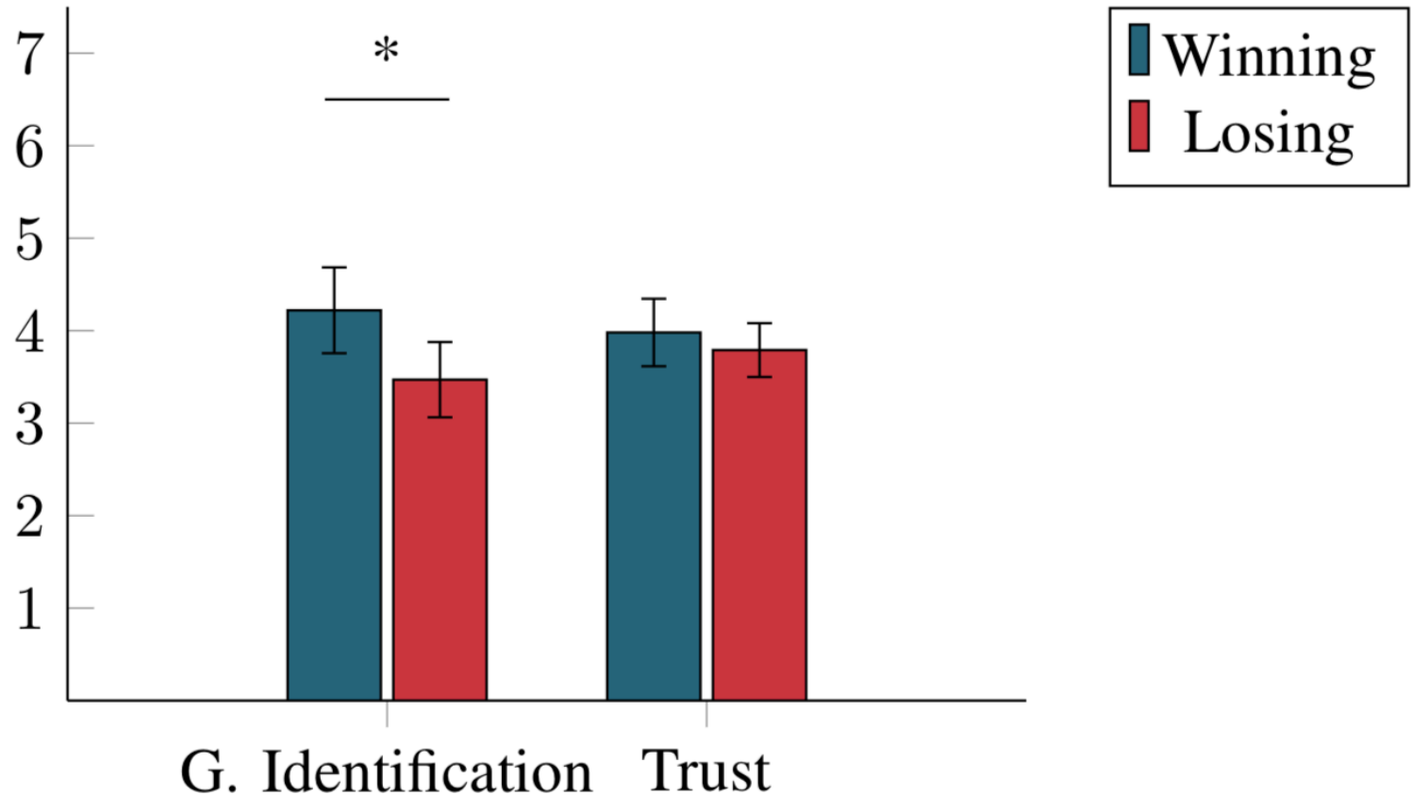
User Study - Results

Group measures



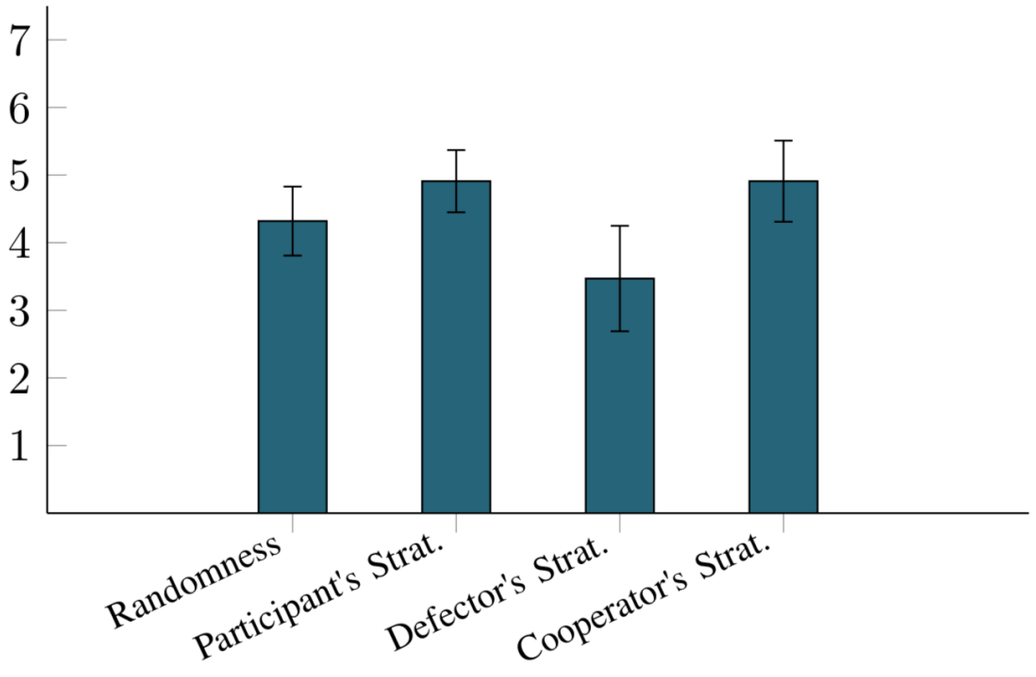
*p=0.014

Correia, F., Mascarenhas, S. F., Gomes, S., Arriaga, P., Leite, I., Prada, R., Melo, F. S. & Paiva, A. (2019, March). Exploring prosociality in human-robot teams. In 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 143-151). IEEE. **[HRI'19]**

User Study - Results

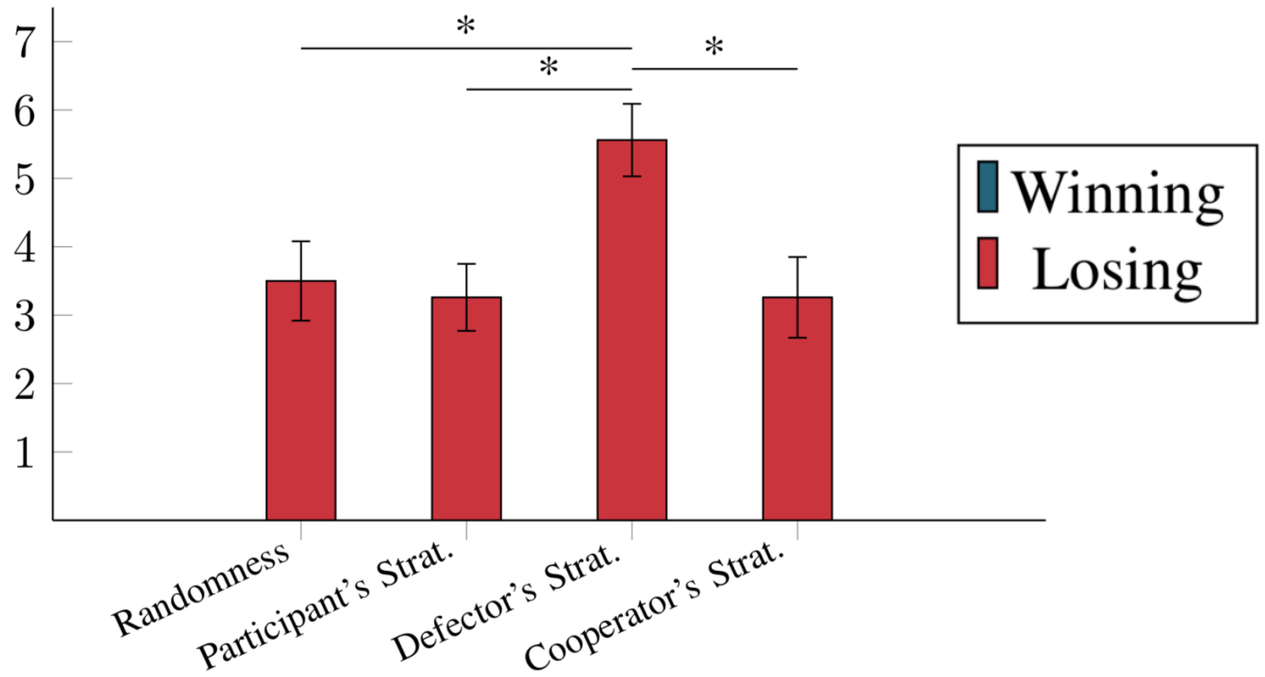
Responsibility attribution of the game result

Credit



p=0.067

Blame

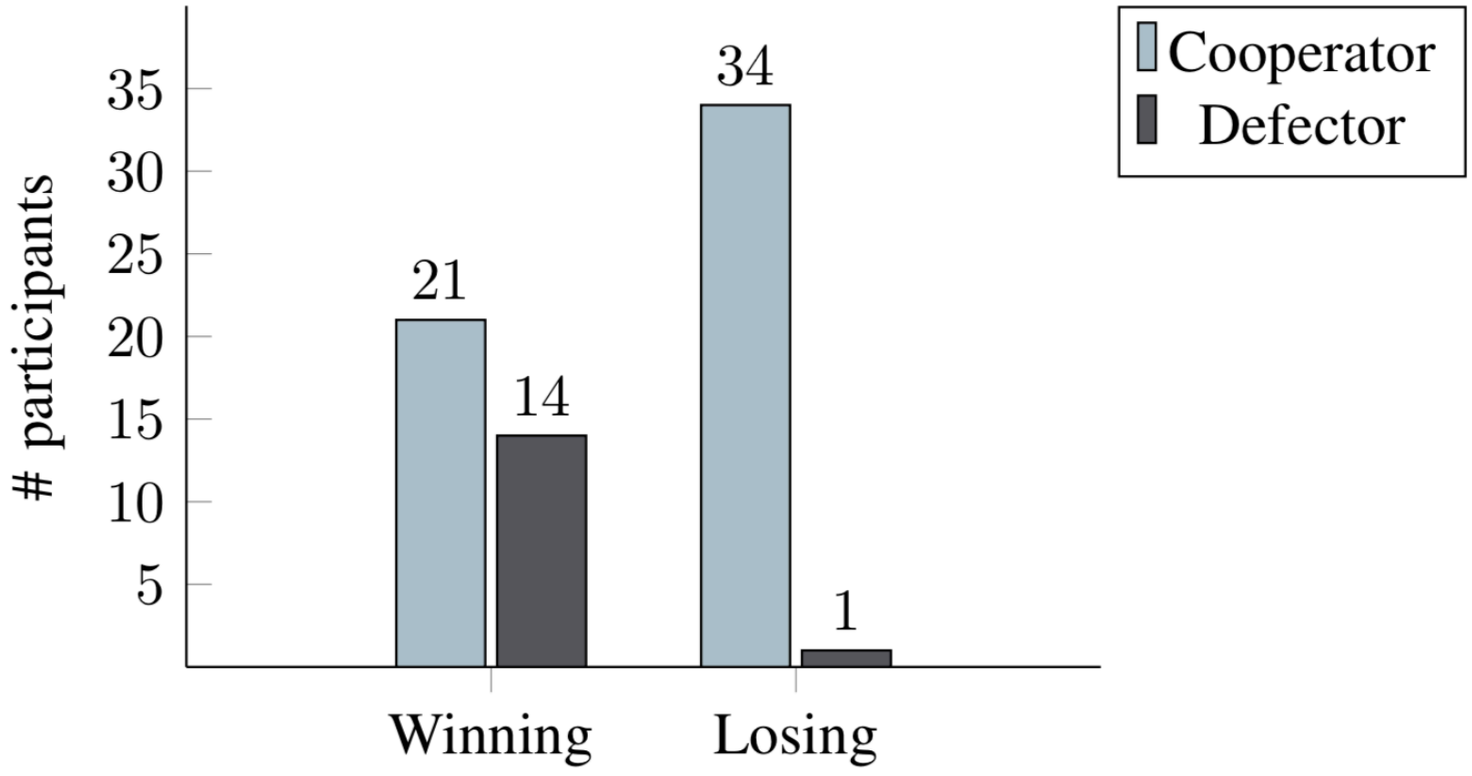


p<0.001

Correia, F., Mascarenhas, S. F., Gomes, S., Arriaga, P., Leite, I., Prada, R., Melo, F. S. & Paiva, A. (2019, March). Exploring prosociality in human-robot teams. In 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 143-151). IEEE. **[HRI'19]**

User Study - Results

Preference for a hypothetical future game



p<0.001

Correia, F., Mascarenhas, S. F., Gomes, S., Arriaga, P., Leite, I., Prada, R., Melo, F. S. & Paiva, A. (2019, March). Exploring prosociality in human-robot teams. In 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 143-151). IEEE. **[HRI'19]**

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…

5. A model of Group-based Emotions

Project Goal & Research Questions

1. Evaluate the impact of the robot's social behaviours on the social cohesion → Membership Preferences & Team Formation

2. Evaluate the impact of the team's outcome on the collective cohesion → Pro-sociality

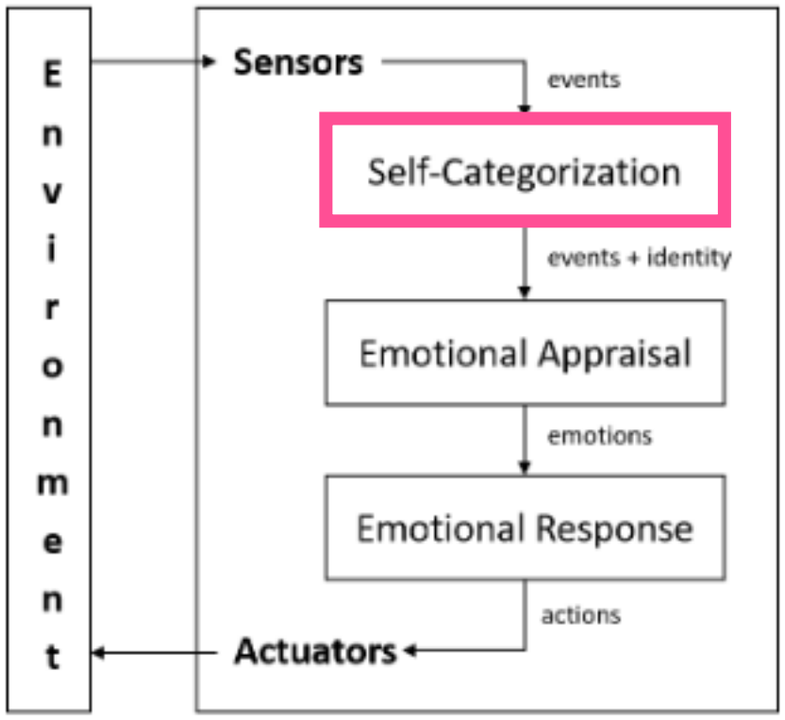
3. Develop computational mechanisms for the robotic teammate to improve collective cohesion → A model of Group-based Emotions

Project Goal & Research Questions

3. Develop computational mechanisms for the robotic teammate to improve collective cohesion → A model of Group-based Emotions

- 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



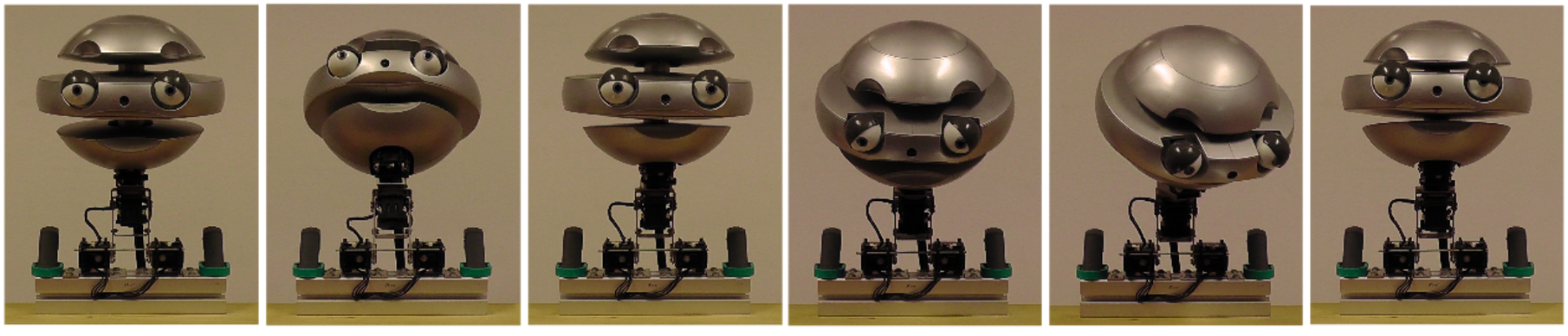
Algorithm 2 Group-based emotions generation process

while true **do**
  $self \leftarrow Robot.Name$
  $e \leftarrow Sensors.PerceiveNewEvent()$
  $SG \leftarrow ContextManager.GetSalientSocialGroups()$
  if $SG \neq \emptyset$ **then**
    $g \leftarrow IdentityManager.SelfCategorisation(SG, self)$
    if $e.ResponsibleAgent \in g$ **then**
      $e.ResponsibleAgent \leftarrow g.Name$
      $self \leftarrow g.Name$
  $AV \leftarrow Appraisal.DetermineVariables(e)$
  $E \leftarrow Appraisal.GenerateEmotions(AV, self)$
  $se \leftarrow StrongestEmotion(E)$
  for all $c \in Actuators.GetEmotionChannels()$ **do**
    $Express(se, c)$

User Study

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

User Study - Manipulation

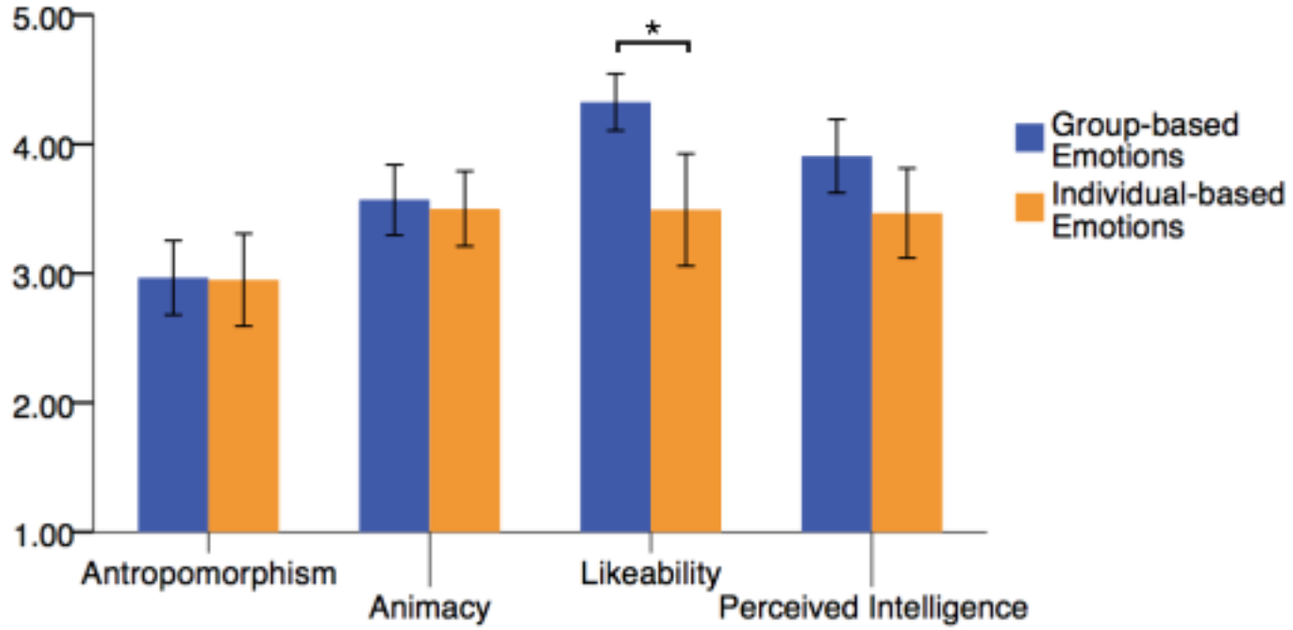


Joy Pride Admiration Distress Shame Reproach

	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)

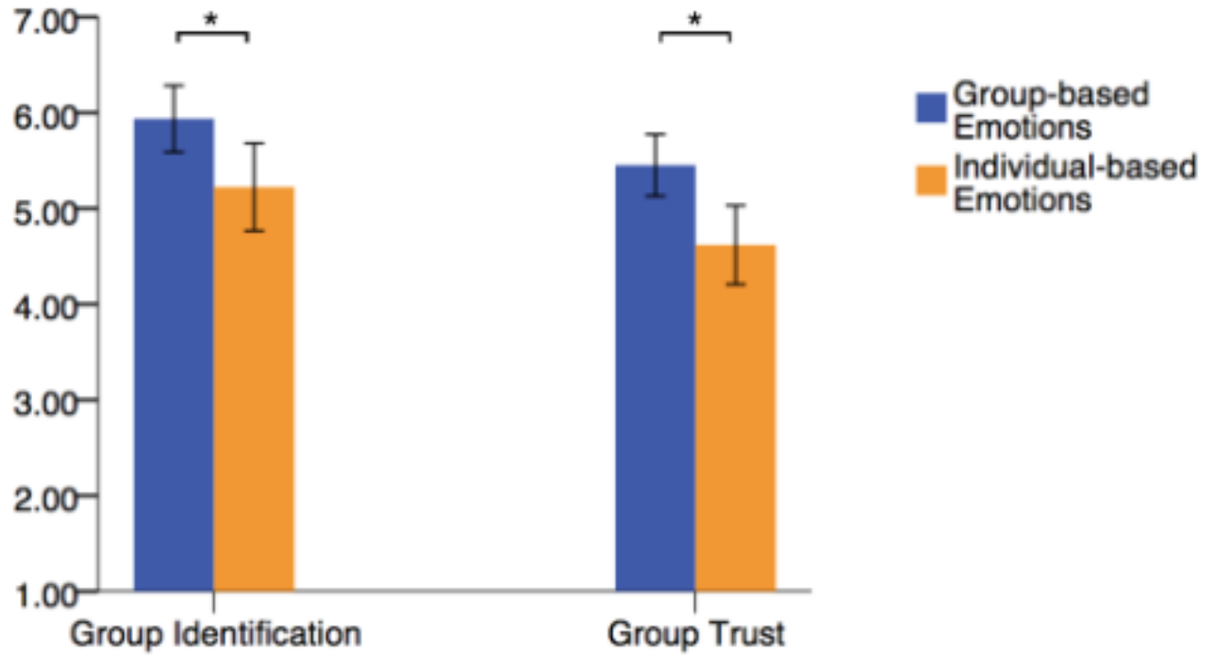


p=0.07 *p=0.79* ***p<0.01*** *p=0.80*

Correia, F., Mascarenhas, S., Prada, R., Melo, F. S., & Paiva, A. (2018, February). Group-based emotions in teams of humans and robots. In Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction (pp. 261-269). ACM. **[HRI'18]**

User Study - Results

Group measures



p=0.02 ***p<0.01***

Correia, F., Mascarenhas, S., Prada, R., Melo, F. S., & Paiva, A. (2018, February). Group-based emotions in teams of humans and robots. In Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction (pp. 261-269). ACM. **[HRI'18]**

User Study - Take-away Message

Group-based emotions should be considered in the design of social behaviours for robotic teammates

6. Communication Network

Project Goal & Research Questions

1. Evaluate the impact of the robot's social behaviours on the social cohesion → Membership Preferences & Team Formation

2. Evaluate the impact of the team's outcome on the collective cohesion → Pro-sociality

3. Develop computational mechanisms for the robotic teammate to improve collective cohesion → A model of Group-based Emotions

4. Develop computational mechanisms for the robotic teammate to perceive the structural cohesion → Communication Network

Project Goal & Research Questions

4. Develop computational mechanisms for the robotic teammate to perceive the structural cohesion → Communication Network

- Can we detect the communication network over time using verbal and/or non-verbal cues?

- Are the features of this network correlated with subjective group measures? Can those features predict any subjective group measures?

Project Goal & Research Questions

4. Develop computational mechanisms for the robotic teammate to perceive the structural cohesion → Communication Network

- Can the robotic agent accurately infer the communication network in runtime?

- How can the robotic agent adapt its behaviour upon perceiving the communication network of its team?

Communication Network

- New scenario - For The Planet

Communication Network

- New scenario - For The Planet
    - Collective Risk Dilemma

Communication Network

- New scenario - For The Planet
    - Collective Risk Dilemma
    - “Upgraded” version of For The Record
        - Non-binary decision

Communication Network

- New scenario - For The Planet
    - Collective Risk Dilemma
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        - Non-binary decision
- Environment and climate change theme

Communication Network

- New scenario - For The Planet
    - Collective Risk Dilemma
    - “Upgraded” version of For The Record
        - Non-binary decision
- Environment and climate change theme
- **Free discussion period before decisions**

Research Plan

- User Study 1 - Data collection with humans-only teams
- User Study 2 - Data collection with human-robot teams
- User Study 3 - Exploring adaptive behaviours

Research Plan

- User Study 1 - Data collection with humans-only teams
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Research Plan

- User Study 1 - Data collection with humans-only teams
- User Study 2 - Data collection with human-robot teams
- User Study 3 - Exploring adaptive behaviours

7. Conclusions

Contributions

Exploring different dimensions of cohesion

A. The influence of robotic social behaviour, namely the portrayal of different goal-orientations, on the attractions between human-robot teams i.e., social cohesion

Contributions

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A. The influence of robotic social behaviour, namely the portrayal of different goal-orientations, on the attractions between human-robot teams i.e., social cohesion

B. The influence of the team's outcome on trust and group identification i.e., collective cohesion

Contributions

Exploring different dimensions of cohesion

A. The influence of robotic social behaviour, namely the portrayal of different goal-orientations, on the attractions between human-robot teams i.e., social cohesion

B. The influence of the team's outcome on trust and group identification i.e., collective cohesion

C. The effect of expressing of group-based emotions on trust and group identification i.e., collective cohesion

Contributions

Exploring different dimensions of cohesion

A. The influence of robotic social behaviour, namely the portrayal of different goal-orientations, on the attractions between human-robot teams i.e., social cohesion

B. The influence of the team's outcome on trust and group identification i.e., collective cohesion

C. The effect of expressing of group-based emotions on trust and group identification i.e., collective cohesion

D. Future work will explore structural cohesion

Conclusions

How can we endow a social robot with the ability to improve the cohesive alliance in a team setting with humans?

Conclusions

How can we endow a social robot with the ability to improve the cohesive alliance in a team setting with humans?

Two major research goals:

- *Investigate how human-robot teams are established from the human perspective*
- *Develop computational mechanisms for the robotic teammate to enhance the team*

Thank you all!

Special thanks to my collaborators:

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Francisco S. Melo (Co-advisor)

Patrícia Alves-Oliveira
Sofia Petisca
Tiago Ribeiro
Samuel Mascarenhas
Samuel Gomes
Patrícia Arriaga
Iolanda Leite
Rui Prada

Publications

- Correia, F., Petisca, S., Alves-Oliveira, P., Ribeiro, T., Melo, F. S., & Paiva, A. (2017, July). Groups of humans and robots: Understanding membership preferences and team formation. In Robotics: Science and Systems. **[RSS'17]**

- Correia, F., Petisca, S., Alves-Oliveira, P., Ribeiro, T., Melo, F. S., & Paiva, A. (2019). ``I Choose... YOU!'' Membership preferences in human–robot teams. Autonomous Robots, 43(2), 359-373. **[AuRo Journal]**

- Correia, F., Mascarenhas, S. F., Gomes, S., Arriaga, P., Leite, I., Prada, R., Melo, F. S. & Paiva, A. (2019, March). Exploring prosociality in human-robot teams. In 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 143-151). IEEE. **[HRI'19]**

- Correia, F., Mascarenhas, S., Prada, R., Melo, F. S., & Paiva, A. (2018, February). Group-based emotions in teams of humans and robots. In Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction (pp. 261-269). ACM. **[HRI'18]**

- Correia, F., Melo, F. S., & Paiva, A. (2019, March). Group Intelligence on Social Robots. In 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI Pioneers Workshop) (pp. 703-705). IEEE. **[HRI Pioneers'19]**

Extra Slides

Research Plan - User Study 1

Ideas for the behavioural analysis:

- What is the content of verbal speeches?
    - Do they blame each other on past actions?
    - Do they negotiate/plan future actions?
- How do those behaviours related with the previous actions of other players?
    - Is there an association between A talking and/or gazing to B according to the previous action of A and/or B?
    - Does the total number of times A talks and/or gazes to B is related to the actions of A and/or B?

Research Plan - User Study 2

Ideas for the behavioural analysis:

- Mutual gaze
- Centrality / unevenness of communication