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

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 social robot with the ability to improve the cohesive alliance in a team setting with humans?*
What is Cohesion?

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What is Cohesion?

- Task
- Emotional
- Structural
- Social
- Collective

What is Cohesion?

- Task
- Emotional
- Structural
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What is Cohesion?

Research Goals

1. Evaluate the impact of the robot’s social behaviours on the social cohesion

Membership Preferences & Team Formation
Research Goals

1. Evaluate the impact of the robot’s social behaviours on the social cohesion

2. Evaluate the impact of the team’s outcome on the collective cohesion

Membership Preferences & Team Formation

Pro-sociality
Research Goals

1. **Evaluate the impact** of the robot’s social behaviours on the social cohesion

2. **Evaluate the impact** of the team’s outcome on the collective cohesion

3. **Develop computational mechanisms** for the robotic teammate to improve collective cohesion

- Membership Preferences & Team Formation
- Pro-sociality
- A model of Group-based Emotions
Research Goals

1. **Evaluate the impact** of the robot’s social behaviours on the **social cohesion**

2. **Evaluate the impact** of the team’s outcome on the **collective cohesion**

3. **Develop computational mechanisms** for the robotic teammate to improve **collective cohesion**

4. **Develop computational mechanisms** for the robotic teammate to perceive the **structural cohesion**

---

**Membership Preferences & Team Formation**

**Pro-sociality**

**A model of Group-based Emotions**

**Communication Network**
2. Related Work
### Related Work

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- Chang et al. (2012)
- Fraune et al. (2019)
- Brandstetter et al. (2014)
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#### Group Identity
- Eyssel & Kuchenbrandt (2012)
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#### Groups of Robots
- Admoni et al. (2013)
- Nawroj et al. (2014)
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#### Group Behaviour
- 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

Membership Preferences & Team Formation

Pro-sociality

A model of Group-based Emotions

Communication Network
Expected Contributions

**Group Identity**
- Membership Preferences & Team Formation
- Pro-sociality

**Group Behaviour**
- A model of Group-based Emotions
- Communication Network
3. Membership Preferences & Team Formation
Project Goal & Research Questions

1. Evaluate the impact of the robot's social behaviours on the social cohesion

2. Evaluate the impact of the team's outcome on the collective cohesion

3. Develop computational mechanisms for the robotic teammate to improve collective cohesion

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

Membership Preferences & Team Formation
Project Goal & Research Questions

1. Evaluate the impact of the robot’s social behaviours on the social cohesion

   • How do relationships and attractions develop towards robotic teammates?

   • What traits do people prefer on robotic teammates?
Goal Orientation Theory

Learning Goal Theory

Goal Orientation Theory

Goal Orientation Theory

Learning Goal Theory

Performance-goal orientation

Learning-goal orientation

Creating two characters

Competitive

Emys

Relationship-driven

Glin

User Study

Which robot will people prefer to partner with?
Development of 2 interactive robots
Development of 2 interactive robots

Development of each interactive robot
Development of each interactive robot

![Diagram showing the interaction between Social Robotic Player, Social Module, Game Module, and behaviors]

- Social Robotic Player
- Social Module (Utterances, gestures, gaze)
- Game Module (PIMC algorithm)

Perfect Information Monte Carlo algorithm
Manipulation of the Goal Orientation

- Emotional non-verbal behaviour
- Scripted verbal behaviour

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<th>Competitive robot (Emys)</th>
<th>Relationship-driven robot (Glin)</th>
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<td>“This cannot continue like this! You have to play better!”</td>
<td>“No worries partner, next time we will do better!”</td>
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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...

First choice of robotic partner

![Graph showing frequencies of the preferred robot]

$p=0.039$


User Study - Results

In the last choice...

![Chart showing frequencies of preferred robotic partners]

\[ p = 0.197 \]


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 the team performance.
4. Pro-sociality
Project Goal & Research Questions

1. Evaluate the impact of the robot’s social behaviours on the social cohesion.

2. Evaluate the impact of the team’s outcome on the collective cohesion.

- Membership Preferences & Team Formation
- Pro-sociality
Project Goal & Research Questions

2. **Evaluate the impact** of the team’s outcome on the 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”
  - 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)

User Study - Results

Social attribute of competence (RoSAS)

![Graph showing the comparison between Cooperator and Defector in terms of winning and losing. The graph indicates a statistically significant difference with p = 0.047.]

User Study - Results

Group measures

* \( p=0.014 \)

User Study - Results

Responsibility attribution of the game result

Credit

Blame

\[ p=0.067 \quad \text{\textit{p<0.001}} \]

User Study - Results

Preference for a hypothetical future game

<table>
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<tr>
<th></th>
<th>Cooperator</th>
<th>Defector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winning</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>Losing</td>
<td>34</td>
<td>1</td>
</tr>
</tbody>
</table>

$p<0.001$

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.
   
2. **Evaluate the impact** of the team’s outcome on the collective cohesion.
   
3. **Develop computational mechanisms** for the robotic teammate to improve collective cohesion.
   
   - Membership Preferences & Team Formation
   
   - Pro-sociality
   
   - A model of Group-based Emotions
Project Goal & Research Questions

3. Develop computational mechanisms for the robotic teammate to improve collective 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 ← Context.Manager.GetSalientSocialGroups()
5:     if SG ≠ ∅ then
6:         g ← Identity.Manager.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

<table>
<thead>
<tr>
<th>Partner increased score</th>
<th>Robot that expresses individual-based emotions</th>
<th>Robot that expresses group-based emotions</th>
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<tbody>
<tr>
<td></td>
<td><strong>Admiration</strong></td>
<td><strong>Reproach</strong></td>
</tr>
<tr>
<td><strong>I am impressed with your move!</strong></td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Partner decreased score</strong></td>
<td>—</td>
<td><strong>With that move, I cannot win.</strong></td>
</tr>
<tr>
<td></td>
<td><strong>We are the best!</strong></td>
<td>—</td>
</tr>
<tr>
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User Study - Results

Social attributes (Godspeed)

![Graph showing social attributes](image)

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

User Study - Results

Group measures

\[ p=0.02 \quad p<0.01 \]

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

- 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

- 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
  - “Upgraded” version of For The Record
    - 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
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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

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
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
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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:

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
Publications


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