Group Intelligence on Social Robots

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***Abstract*—This PhD project aims at investigating how a social robot can adapt its behaviours to the group members in order to achieve more positive group dynamics, which we identify as group intelligence. This goal is supported by our previous work, which contains relevant data and insightful results to the understanding of group interactions between humans and robots. Finally, we examine and discuss the future work we have planned and what are the contributions to Human-Robot Interaction (HRI) field.**

***Index Terms*—Social Robots, Group Dynamics, Trust, Group Identification, Membership**

I. Introduction

The field of Human Robot Interaction (HRI) started to address group interactions in the past decade, contrasting to the most traditional dyadic settings, i.e. single human and single robot interactions. Consequently, the dynamics of groups where one or more robots engage with one or more people introduces a broad set of new research questions. For instance, Jung et al. posed the following question in [1]: "How can robots improve the performance of work groups and teams by acting on social processes?".

One of the first findings related to human-robot groups and teams was introduced by Hinds et al. [2], where the results of a user study revealed more blame attribution to a robot that had the role of a supervisor compared to peer or subordinate. Later, Jung et al. showed a group of robots using a backchanelling behaviour were capable of improving the stress levels and cognitive load of their human group members [3]. Recently, Fraune and collaborators examined how different group structures affect humans' perceptions, namely the composition and the diversity by manipulating size and behaviour (social or functional) in [4], size and type (anthropomorphic, zoomorphic or mechanomorphic) in [5], and entitativity in [6].

Although current literature already explores some aspects of human-robot dynamics in groups and teams, most of them analyse the individual interaction with group members [7], [8]. The novelty of our project, however, is to shed light on how the interaction with the whole group should accommodate the individual differences of each member. Our motivation relies on the singularity each member introduces on interpersonal groups and teams, which makes every single group unique [9]. Moreover, previous findings already support processes such as social categorisation, and some of its inherent ingroup bias, also apply to robots [10], [11]. As a result, we propose to investigate how a social robot can adapt its behaviours to the group members in order to achieve more positive group dynamics, which we identify as group intelligence.

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II. Research Plan

Our project aims at exploring how a social robot can possess capabilities of group intelligence in order to foster positive group interactions with humans. This notion of group intelligence holds on two premises: an awareness of the group situation that counterbalances the state of each member; and a behavioural adaption of its individual goals to the group goals. This long-term vision introduces several intermediate goals that constitute the research plan for our project:

(1) To understand how humans perceive and evaluate the interaction between a mixed group of humans and robots;
(2) To understand which individual-, team- and task-related characteristics affect such perception and evaluation of the group;
(3) To develop mechanisms for a robot to autonomously perceive and evaluate the group in real-time;
(4) To develop mechanisms for a robot to autonomously cope and optimise the dynamics of a human-robot group.

Our previous work was mainly focused on the goals (1) and (2), in which we explored possible metrics to analyse and assess how humans perceive each group member and how they evaluate the membership. The future work will reach sequentially the goals (3) and (4). Our previous work contains relevant data and insightful results to the understanding of group interactions between humans and robots, which strongly supports the execution of the remaining goals.

A. Previous Work

Our first investigation on group interactions between humans and robots explored the collaborative and competitive setting of a team game. We analysed how humans develop trust towards a robotic partner and compared it to the trust development towards a human partner [12]. The results of a user study suggested that the measure of human-robot trust requires repeated interactions in order to increase, which supports the complexity of this construct [13].

In another investigation using the same scenario, we conducted a user study with two mixed teams of humans and robots, and we manipulated social behaviours of each robotic partner by attributing different goal orientations [14]. The

results suggest that there are many factors influencing the choice of a robot for a future partnership. For instance, participants aligned their competitiveness level with perceived competitiveness of the chosen robot, as they have also aligned their choice with the perceived performance of the team. The behavioural data of this user study was extensively analysed in [15], using the Interaction Process Analysis, proposed in [16]. The results provided evidence of different interaction patterns towards robots that display distinct goal orientations and also depending on its role in the group, being a partner or an opponent.

In our demand for the understanding of how people perceive and evaluate group interactions among humans and robots, we decided to also explore group identification [17]. In particular, we compared whether the display of group-based emotions [18] by a robotic partner, compared to the display of individual-based emotions, could increase the social identity of a human-robot team [19]. Our results suggest there is a strong and positive impact of group-based emotions, which not only enhance the group identity, but also improve the group trust.

Recently, we have created a new scenario that is an N-person social dilemma, inspired by the inherently collaborative public goods game. In a first user study with 3 players, 2 robots and 1 person, we have manipulated the game strategies of each robot and the outcome of the game, namely whether the game ends in victory or defeat [20]. Results showed that the strategy a robot takes during the game (between a more selfish and a more collaborative action) is capable of changing the human perception of its social attributes. Moreover, the outcome of the game had an impact on the preference for a future partner, on the responsibility attribution of the result, on the perception of competence, and on the group identification. An additional contribution was a regression analysis that examined how the perceptions of each group member are related to the measures of group trust and group identification.

Overall, our previous work has examined several measures that can be used to assess how humans perceive and evaluate the interaction of a human-robot group. Furthermore, we have identified some aspects that affect these perceptions and evaluations, by manipulating social or task-related behaviours of a robotic partner. Finally, we consider our new scenario constitutes an adequate interface to further study and analyse the dynamics of human-robot groups.

B. Future Work

In order to accomplish our third goal of developing mechanisms for a robot to autonomously perceive and evaluate the group in real-time, we are planning to extensively analyse the commonality between all the measures we have used so far (i.e. group trust, group identification, responsibility attribution, socioemotional support). Then, we aim to define a set of possible behavioural modalities (e.g., voice and/or visual cues) to detect on each group member, and to explore their predictive power with respect to the group dynamics. Additionally, we are also planning to assess emotional expression of each group member as it has been recently shown that it relates to how humans identify themselves as part of a group [21]. We expect to contribute with a good predictive model of group identity and emotional cohesion, which can endow a robot with an autonomous perception of the group situation.

The last goal of our project envisions the ability to adapt the actions of a robot according to the interaction of a certain group. Our previous work supports the fact that both socio-emotional and task-related actions by a robotic partner can affect the perception humans have of the group. Nonetheless, group dynamics in interpersonal relations consider much more complex patterns that establish delicate considerations to understand and modify group interactions, e.g. behavioural synchrony [9] or conflict interaction [22]. Some of those behaviours are being recently explored in HRI as, for instance, social dominance [23].

Our future goals (3 and 4) are interdependent as the desired adaptive behaviour is dependent on the achievements of the aforementioned real-time awareness of group state. However, a clear example that we aim to develop towards the behavioural adaptation is the robotic partner changing its emotional responses according to the mean emotion of the group. Goldenberg et al. have recently shown that group identification is higher when the variance of mean emotion of the group is lower, and that group identification is lower when participants' own emotional response diverges from the mean emotion of the group [21]. As a result, we expect that a social robot capable of performing adaptive behaviours according to some of those dynamics can enhance human-robot groups.

III. Contribution and Impact

The relevance of studying group dynamics is mainly attributed to the influential power a group can have on the values, attitudes, and perceptions of their members [9]. As the presence of social robotic machines in our daily lives grows, the pertinence of analysing these research questions in HRI becomes clearer. The research plan of our project contributes to the understanding of group dynamics where robots collaborate with humans. Furthermore, it envisions social robots that adapt and enhance the group interaction and, in a more general perspective, can positively influence society.

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