Social robots as leaders: leadership styles in human-robot teams*

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Abstract— **This paper explores robotic leadership and the impact of different human-leadership styles in teams leaded by social robots. It is anticipated that social robots can have the capability to serve as leaders for human teams and to collaborate with humans in order to improve the organizational requirements of the workplace environment. We report an experiment conducted in order to determine which human-leadership styles would be associated with better results in organizational phenomena, such as, employee productivity, role ambiguity, engagement and employee satisfaction. The sample comprised 108 collaborators divided in 36 teams, who had to perform a collaborative task with a robotic leader acting according to two different leadership styles. The experiment results showed that both leadership styles can have positive impacts in organizational outcomes, although in different aspects. These findings yield important insights for the creation of robotic partners and for the successful introduction of robots as leaders of human teams.**

I. INTRODUCTION

The last years have been marked with the rapid development of the artificial intelligence field and its subsequent applications in several scientific areas, such as human resource management. The recent advances in human-robot interaction field are compelling humans to work more closely with robots and to successfully integrated them in the work environments [24].

Following these developments, it is expected that social robots in a near future could have the capability to serve as managers and leaders for human teams [23], which can also have applications for the organizational environment. In fact, some studies involving mixed human-robot teams already demonstrated that individuals tend to favor ingroup robots over outgroup humans [24], which implicates that people accept well to work alongside robots and consider them as part of the team. In this context, research in human-robot interaction scenarios and leadership roles are particularly valuable, as suggested by some authors [12].

As the role of robots in the workplace is evolving, research in human-robot interaction and the proper roles needed for this integration is crucial [24]. In human-robot interaction field, some investigations already argued that humans have a natural tendency to attribute human characteristics to non-human objects, such as robots. Additionally, robots can have the potential to trigger attribution of mental states, as long as they display observable signs of intention, similar to human behaviors [21]. This can mean that individuals have the ability to see intention in robots' behaviors.

Additionally, previous studies already established that robots have the capability to reproduce leaders behaviors in order to execute leadership tasks [6, 25]. Both humans and robots can collaborate together in order to maximize the strengths of each, and additionally, the organizational requirements of the environment.

Among the several human-leadership paradigms addressed in management literature, transformational and transactional leadership styles are the most commonly mentioned, being part of the full-range leadership model by [2]. A transformational leader motivates and inspires their followers to increase their productivity to accomplishing a common goal, directing their behavior toward a shared vision [3]. Factors such as exhibition of charismatic behaviors, intellectual stimulation and inspirational motivation have been associated with transformational leadership [2]. A transactional leader focuses on supervision, organization and clarification of expectations, providing recognition if goals are achieved [2]. Following this theoretical line, it is important to explore which leadership styles and respective behaviors are most appropriate for a robot to display. Adopting human-leadership styles in human-robot interaction scenarios can help to identify and adjust robots' characteristics to specific contexts, in order to facilitate humans' acceptance of robotic leaders in work environments [6, 17].

In this paper we describe a study conducted with teams of humans lead by a robot in the performance of a task, while the robot follows either a transformational leadership style or a transactional leadership style. One of the innovative factors of this research is its real-context human-robot interaction, where participants interact and share the same space with an actual robot. Most of the research in this field is based on hypothetical/imagination scenarios or non-experimental studies, so we believe our data can bring more trustworthiness regarding the use and acceptance of robots in work environments.

II. LEADERSHIP STYLES AND ORGANIZATIONAL OUTCOMES

A. *Productivity*

Management and leadership literature have been characterized by inconsistent findings regarding the impact of leadership styles in employees' and teams' productivity.

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Bass and colleagues [2] stated that both transactional and transformational leadership styles can contribute to increased performance and productivity, which supports the preposition that a mix of both leadership styles can lead to successful organizational outcomes [5, 15]. However, a group of investigations have been associated transactional leadership with better productivity levels [16, 29]. This can be explained because transactional leadership reflects a focus on task accomplishment, contrary to transformational leadership that is more focused on person-based aspects. In robotic leadership, transformational features are less expected to be demonstrated by robots, since characteristics such as inspiration, motivation and charisma are considered to be more 'human-like' [5]. Thus, if people have non- experience in working alongside robotic agents, it is expected that they demonstrate higher productivity when their leader is focusing on task characteristics, errors and providing explanations [5], because they are being more focused-oriented for the results and pragmatic, which is expected for a robot to do. For this reason, we hypothesized:

H1: Teams' productivity will be higher in the condition where the robot acted as a transactional leader than in the condition where the robot acted as a transformational leader.

B. Engagement

Among the variables that have been studied as affecting leadership styles, engagement is one of them [22]. Having engaged employees is one of the top priorities that an organizational leader should have [3]. Since engagement and productivity are two distinct constructs, this means that they can be differently affected by leadership styles. Thus, engagement can benefit more from a transformational leadership style and productivity can be more affected by a transactional leadership style. Confirming these assumptions, the literature has been linked transformational leadership styles with higher levels of employee engagement [3, 22] which can be explained by the particular characteristics that this leader-follower relationship presents. Transformational leaders motivate and empower their subordinates, raising confidence and inspiration in their relationships, which in turn fosters workers' engagement. In contrast, transactional leaders tend to be action-oriented and only focused on teams' results, promoting leader-follower relationship through contingent rewards [15]. Consequently, transactional leadership has been linked to lower levels of workforce engagement [11, 28]. In human-robot interaction scenarios we expect to find similar results regarding the impact of the robot' leadership style in teams' engagement, so we hypothesized:

H2: Teams' engagement will be higher in the condition where the robot acted as a transformational leader than in the condition where the robot acted as a transactional leader.

C. Role Ambiguity

Role ambiguity occurs due to insufficient information required for adequate role performance in organizational tasks [18]. Transformational leaders are expected to clarify role expectation, which can reduce role ambiguity [19] . Several investigations have shown that lower levels of role ambiguity are associated with transformational leadership behaviors [20]. On the opposite way, transactional leadership characteristics are more associated with focus on efficiency, less flexibility and the use of punishments to encourage compliance of the rules. Such features may induce higher levels of uncertainty and ambiguity, which can increase teams' role ambiguity [19] . However, some investigations found no association between transactional leadership and role ambiguity [19]. Since several investigations have confirmed that transformational leadership style is associated with lower levels of role ambiguity [18, 28], the following relationship is expected:

H3: Teams' role ambiguity will be lower in the condition where the robot acted as a transformational leader than in the condition where the robot acted as a transactional leader.

D. Human-robot interaction

Among the different aspects of social interaction with robots, individuals' trust in robots is a key-point for facilitating success in human-robot interaction scenarios [30]. The lack of trust and willingness in interacting with artificial intelligence machines may instigate people's hesitance in using technological agents [23]. Previous research suggest that individuals express more positive attitudes and trust toward robots when robots seem to have good communication capabilities [9]. For robotic leadership to be an actual reality in organizations, a collaborative and reliable relationship must be built between social robots and the organizational agents [25]. Since transformational leadership is characterized by a set of inspirational, motivation, intellectual stimulation and individual considerations [4], we expect to find higher levels of human-robot trust associated with transformational leadership style:

H4: Teams will show higher levels of human-robot trust in the condition where the robot acted as a transformational leader than in the condition the robot acted as a transactional leader.

III. Methodology

A. Procedure

The study was run following a between groups approach. Each group performed the same task with the same set-up except for the behaviour of the robot that was set to perform as a transformational leader or a transactional leader.

All the participants signed the consent form and then proceeded with the experiment. The researcher introduced the robot, the task rules and answered participant's questions. It was emphasized that participants should follow the leader's instructions to be successful in the task. Participants were asked to work on an interdependent, highly engaging task, commonly known among researchers as "the marshmallow challenge" [8]. The teams had to build the highest possible tower in 18 minutes using the following construction materials: 20 sticks of spaghetti, play-doh, and one marshmallow. This task was considered appropriate for testing the research hypotheses since it supports collaboration and coordination with the team leader, and it is interesting enough to engage participants.

Teams began the session with the robot while the researcher stayed on a distant table in the room, where all the interaction could be observed, and the robot could be remotely controlled. The researcher was choosing the robot utterances in real-time during the experiment, through a laptop containing the wizard-of-oz interface (Fig.1).

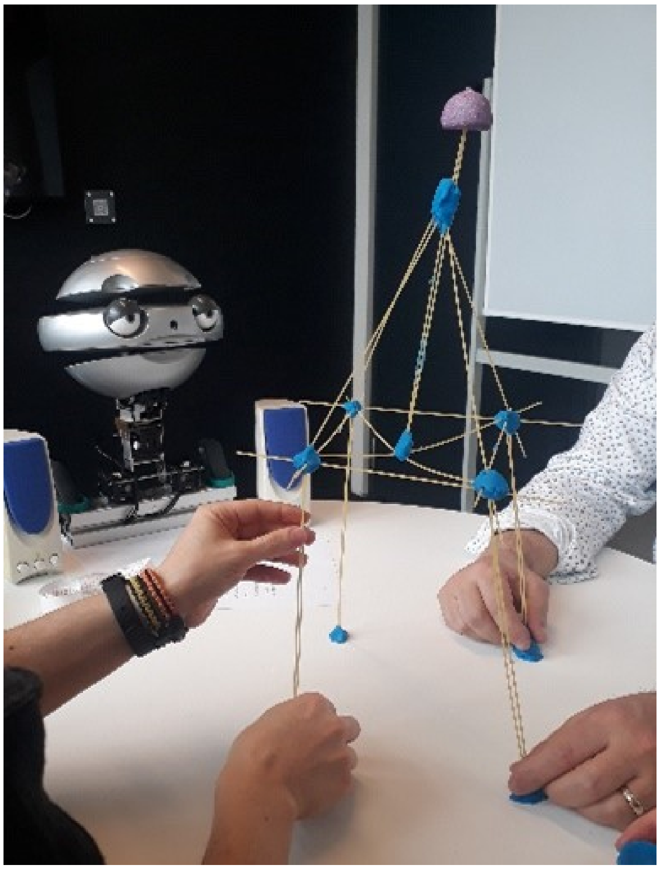

Fig. 1. This interaction was captured during a session, where the team is performing the task following the instructions of the robot leader.

After the task, the participants answered a questionnaire that took approximately 15 minutes to complete. No rewards were given to the participants.

B. The robot

The robot used in the study was EMYS, a robot specifically designed for human-robot interaction experiments. It has the capability to move his head, to speak and to use some facial expressions while interacting with users. Despite using a "Wizard of Oz" paradigm we used the robot's default "lifelike" behaviour that makes it move the head to gaze around and present slight facial expressions. This behaviour was the same for both conditions. We implemented the leadership strategies through the sentences of the robot's speech during the task.

The participants were under the belief that the robot leader was fully autonomous, however it was in fact controlled by the researcher in the room, without the participants realizing it. The ethics commission of the university approved the use of the human-robot interaction under the conditions of this experiment.

C. The Script

To help defining the scripts for the robot's speech, nine critical situations were previously established, corresponding to the nine moments during the task' duration where the robot leader would have to intervene. The nine situations where: a) the introduction of the task and its explanation; b) the first minutes of the task, when the team is building the tower foundation; c) when the team is finishing the foundations and trying to make it stable; d) giving support for the task execution halfway through the task's duration; e) giving support for reinforcing the tower and its structure halfway through the task's duration; f) giving support while the team is building the intermediate floors of the tower, focusing on the increase to the tower's height; g) giving support and focusing the attention of the participants on floor instability; h) when the team is building the top of the tower; i) in the final stage of the task, focusing the attention of the participants on making the top of the tower stable and accomplishing the task in the remaining time.

The two scripts were developed to enable the maximization of the emergence of the characteristics of a transformational leader or a transactional leader, as described in the literature [2]. Multifactor Leadership Questionnaire [1] and Global Transformational Leadership scale [7] were carefully scrutinized in order to develop utterances that would completely reflect each leadership style behavior that the robot had to demonstrate. For each one of the nine situations, a set of sentences was developed, with each sentence being supported in the corresponding literature. For instance, in the situation A (introduction of the task and its explanation) the sentence "I will give you support and ideas so we can build the highest tower together" for the transformational leadership style was inspired, developed and substantiate from [7, p. 396] sentence "communicates a clear and positive vision of the future". The corresponding sentence for the transactional leadership style "I will make sure that you accomplish the goal of building the highest tower" was inspired, developed and substantiate from [1] sentence "I tell others the standards they have to know to carry out their work". Table I shows some examples of the script sentences that were developed, for each leadership condition.

Finally, the scripts were validated by six researchers and academic professors from the fields of organizational behavior and human resource management. A moderate degree of agreement was found between the six raters. The average measure of Intraclass Correlation Coefficient (ICC) was .447, confirming that both scripts reflected properly each leadership style.

D. Sample

The sample comprised 108 collaborators from three Portuguese companies, divided in 36 teams of 3 participants each. The respondents were 52.8% females and 47.2% males,

TABLE I

EXAMPLE PHRASES FOR EACH LEADERSHIP STYLE

Transformational Leadership style	**Transactional Leadership style**
"I will give you support and ideas so we can build the highest tower together."	"I will make sure that you accomplish the goal of build the highest tower."
"Let's move forward team, I trust your work, we are being efficient."	"Let's move forward team, you have to be efficient to accomplish the task."
"We're on the right direction, I'm really enjoying our performance".	"'You're on the right direction, but more effort is needed team".
"We had a good performance, I'm very proud of our work team."	"You managed not to have many errors, the goal was accomplished team."

both aged between 21 and 66 years (M = 37.40; SD = 11.09). The average of seniority in the companies were 8.02 years. The majority of the participants (49.1%) reported to have a university degree and 39.8% reported to have a master's degree.

E. Aggregation

The level of analysis of interest in this study was the team. Therefore, all individual team members' responses were aggregated to the team level for further analysis, resulting in 19 teams for the transformational leadership style condition and 17 teams for the transactional leadership style condition.

IV. MEASURES

A. Overall team's productivity

The overall team's productivity was measured by the height of the tower (in centimeters) at the end of the time available to perform the task.

B. Teams' Engagement

Teams' engagement was measured from a 12-item scale by [12], an instrument that was designed to measure two global dimensions of the Engagement construct, namely Emotional Engagement and Physical Engagement. Emotional Engagement assesses the extent to which people experienced positive feelings about their work in the assigned task (e.g., "I am proud of my work") and Physical Engagement assesses the extent they invested physical energy and effort in their task (e.g., "I have devoted a lot of energy on my work."). The Cronbach alpha was .91 for the 12 items, with an explained variance of 52.77%.

C. Role Ambiguity

Role Ambiguity was measured through six items developed by [13]. It measures the lack of clarity of role expectations and the degree of uncertainty regarding the outcomes of one's role performance (e.g., "I knew exactly what was expected of me"). All items of this scale are reversed, which means that higher values in this scale are associated with lower levels of role ambiguity. The Cronbach alpha for the six items was .84 and the construct validity suggested an Exploratory Factor Analysis with 60.78% of total explained variance.

D. Human-Robot Trust

Human-Robot trust was measured with an adapted version of the Human-Robot Trust Scale by [15]. From the original 40 item-scale, only 25 items were selected according to its relevance to the purposes of the research. Items were preceded by the question "What percentage of the time did the robot leader ...(...)" followed by a list of the 25 items [26]. Following the authors' guidelines, the scale was administered directly following the interaction with the robot. The Cronbach alpha was .91 for the 25 items, with an explained variance of 78.07%.

E. Manipulation check: robot automatization and leadership styles

Each participant was asked to answer in a 7-point Likert scale the extent to which they perceived the robot's performance as being totally spontaneous (1) or controlled by the researcher in the room (7). The average response rate was 2.40 (SD=2.2), which means that the manipulation has succeeded.

Likewise, teams' perception of the robot leadership style was also verified, in order to determine if the participants perceived in each condition the robot as acting as a transformational leader or as a transactional leader. To measure each leadership style, participants responded to an adapted scale from [7], that measures transactional and transformational leadership styles in a 5-point Likert scale. In the transformational leadership condition, participants reported an average rate of 3.96 transformational perceived behaviors (SD=.66) compared to 2.95 transactional perceived behaviors (SD=.59). In the transactional leadership condition, participants reported an average rate of 3.92 transactional perceived behaviors (SD=.46) compared to 2.95 transformational perceived behaviors (SD=.59). There were statistically significant differences between the conditions [$F(1, 34) = 11.864$, $p < .005$], which means that the manipulation of the robot leadership style has succeeded.

F. Manipulation check: robot's perception as a team leader

Participants were asked, in a manipulation-check questionnaire, the extent to which they perceived the robot as a team leader (1) or a teammate (10). The average response was 4.08 (SD= 1.79) which indicates that in general participants perceived the robot as a team leader.

V. RESULTS

All analyses were conducted using IBM SPSS Statistics version 25. A one-way between subjects ANOVA was conducted to compare the effect of robot's leadership style (transformational or transactional) on the height of the towers constructed by the teams. There was a significant effect of the leadership style on the height of the towers for the two conditions [$F(1, 34) = 4.240$, $p < .005$, $\eta^2 = 0.110$]. On average, when the robot acted as a transactional leader the teams built higher towers (M= 49.29, SD=14.46) than when the robot acted as a transformational leader (M= 39.16, SD=14.98), confirming hypothesis 1. There were also a main effect of the leadership style presented by the robot in the engagement level reported by the teams [F (1, 34) = 7.075, $p < .005$, $\eta^2 = 0.172$]. On average, in the presence of a transformational robot leader the teams reported higher levels of engagement (M= 4.40, SD=.28) compared with the transactional leadership condition (M= 4.14, SD=.31). These results are in line with hypothesis 2. Teams also reported higher levels of role ambiguity in the transactional leadership condition ((M= 5.49, SD=.66) compared to transformational leadership condition (M= 5.77, SD=.80). Although these results are in accordance with the direction of hypothesis 3, no statistically significant differences were found between the leadership style type and the role ambiguity level reported by the teams [F (1, 34) = 1.363, p =.251]. The teams also reported higher levels of robot-trust in the transformational leadership condition (M= 59.98, SD=13.21) than in the transactional leadership condition (M= 54.93, SD=10.28). However, these results are not statistically significant [F (1, 34) = 1.609, p =.213], so we did not find support for hypothesis 4.

VI. Discussion

This study used an experimental design to investigate the relationship between human-based leadership styles and robotic leadership. By adopting a human-leadership paradigm, it was assessed which robotic-leadership approaches would be associated with better organizational outcomes. Our results showed that in human-robot interaction contexts, both transactional and transformational leadership behaviors can have positive impacts regarding distinct organizational outcomes. This is in accordance with human-leadership literature that states that mix these two leadership styles is the most appropriate solution to meet the demands of a more technological work environment [2, 10, 14]. This study can be useful to organizations considering adopting social robots in their work environments. Several configurations of robots can be programmed in order to maximize the best features of each leadership style, which is not that easy to do when leaders are humans and can be a major advantage of robotic leadership.

Role ambiguity was revealed to not be significantly impacted by either conditions, which can be explained by the nature of the task the teams had to perform. Since both conditions had the same time, the same rules and the same materials to perform the task, they already had a set of information regarding what they were expected to do, which can explain the absence of differences [4]. Regarding human-robot trust the results were also not significant, which can be explained by some robot design factors (such as verbal communication, facial expressions, automatization) that have been linked with the development of trust in robots [27]. Teams only had thirty minutes to interact with the robot leader which, due to the need for more time for individuals to establish a trusting relationship with artificial agents, can also help explain the results [27].

The current study's limitations need to be considered when interpreting the above findings. Our results should be prudently examined, because participants' previously experience in working with robots was not controlled. However, the research team have some beliefs to consider that it was indeed a first human-robot interaction experience for all the employees who participated in the experiment. The teams also interacted and worked with the robot in only one-single task. It would be interesting to analyze in a longitudinal study the impact of robotic leadership in organizational outcomes. Efforts should be made in order to understand the process of developing a long-term relationship with an robotic leader.

Understanding human-robot trust across team members in real organizational settings should be the focus of future research in human-robot interaction field, controlling the variables that may affect this relationship. More studies should be developed in order to create meaningful work experiences while working with robots. Additionally, upcoming work should also investigate which factors can improve productivity and performance in teams leaded by a robotic agent. Combining each leadership style in order to exploit the benefits of the human/robot workforce should be one of the focus of future studies in human-robot interaction field [23]. Likewise, one of the forthcoming challenges for human-robot interaction research must be to provide the robots the capacity to choose when to use each leadership style when interacting with human teams.

VII. Conclusion

The world is progressively forwarding to a society where robots will be able to work with humans in work environments, collaborating and assisting human teams in accomplishing greater organizational results. To our knowledge, this is one of the first investigations to study in an experimental setting robotic leadership styles in human teams. Robot-based leadership will have a promising future in the following years, and the upcoming technological developments may be applied to create more effective work environments.

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