OPEN ACCESS

Journal of Advanced Research in Leadership
eISSN 2783-5928

Human Robot Interaction - Key Areas in Teamwork

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ARTICLE INFO

Keywords:
human robot interaction,
human robot teams

ABSTRACT

Industry 4.0 is based on the implementation of smart technologies. Work teams consisting of humans and intelligent machines, such as robots, are becoming more common. Their cooperation is based on joint performance of tasks in order to achieve set goals. The aim of the article is to present the challenges associated with the functioning of new types of work teams in organizations: based on cooperation between people and intelligent machines (robots or artificial intelligence algorithms).

The article discusses the impact of factors such as trust, mental models, human personality, and machine reliability on the functioning of human-robot teams. It is shown how these areas can affect the performance of HRI - Human Robot Interaction Teams. The literature analysis indicates that before valuable human-robot interaction can occur, humans must first build trust in the machines. And the reliability of robots, and the human sense of control over them, increases trust. In addition, human personality and the attributes presented by a robot are also important for cooperation. For example, robots perceived as extroverted and socially intelligent have a high level of acceptance from humans.

1. Introduction

In Poland, currently the most robotized sector in industry is the manufacture of products of rubber and plastics (117.8 robots per 10,000 employees). In the automotive branch, the rate is 165.5 robots per 10,000 employees, according to the report "Has the pandemic accelerated robotization?" prepared by the Polish Economic Institute. The data also shows that the pharmaceutical industry is rapidly being robotized (111 robots per 10,000 employees). Although the process of robot implementation in Poland slowed down during the pandemic period, the authors of the report believe that in the long term the process will nevertheless progress. However, the road of development is far, a considerable distance separates Poland from the top of the most robotized European countries (PEI, 2019). According to the data contained in the "Forecast of robotization development directions in Poland", the largest European market is Germany, with 22,302 robot installations in 2020, at which time it represented 32.9% of the European market. The second most important is Italy, and the third is France (DBR77 Robot Platform, 2022).

International corporations such as Amazon and Google are investing extensively in

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Cite this article as:
Morze, M. (2022). Human Robot Interaction - Key Areas in Teamwork. *Journal of Advanced Research in Leadership, 1*(2): 9-17. https://doi.org/10.33422/jarl.v1i2.158

robotization. In 2012, Amazon claimed to have deployed 30,000 robots in 13 order fulfillment centers. In early 2019, Amazon reported that it had already implemented more than 100,000 robots, in more than 25 fulfillment centers across the United States (Lambrechts, 2021). Between 1993 and 2018, the number of industrial robots worldwide increased from 557,000 to 2.4 million. The most rapid growth was in 2014-2018, year-on-year the number of robots grew by more than 10% (PEI, 2019). When looking at the statistics, one can believe that there is no turning back from robotization and automation. The only thing is that working with machines, is not an invention of the fourth, but of the second industrial revolution. What is changing, of course, is the type of machines, their capabilities and the way they cooperate with human operators. As robots become more autonomous, their role is changing from being operated and controlled by humans to interacting with them. (Demira, 2020). Before we move on to the topic of human-robot interaction, it is worth clarifying exactly which machines and what type of cooperation we are talking about. The description of the types of cooperation, is well exemplified in the classification presented by KUKA, which describes six levels of cooperation between humans and robots. The first level is total separation (fixed safety fence), in this arrangement the human operator is isolated from the machines, so they can work quickly and forcefully. The second level, named - shared workspace (occasionally ahared workspace) - a human operator can safely stop the machine and enter the space where it is working to, for example, supplement or replace components . The next level, named - virtual separation - this is where the collaborative space is partially separated, but so as not to obstruct contact between the operator and the machine. Shared Workspace fourth level - the space is shared. The human works with the robot constantly, but direct contact is not necessary. The fifth level (robot and operator must work together to complete process) requires that man and machine work together to complete the activities planned in the process. The highest, sixth level of cooperation is with autonomous robots. Humans move with robots over a relatively large common area, cooperation takes place in many places. So when is a robot only technology, and since when does it become a member of a work team? Some researchers make a distinction between technology and an artificial agent - a team member. Suggesting that the term technology should be reserved for those devices, software, etc. that are directed at team members, with the aim of improving team processes. So, they recommend using the term technology when referring to its role as supporting team operations. A robot, can be either a technology or an agent, depending on its role in the team. If the robot merely extends the human, making no unique contribution to the team other than to increase the human's efficiency - then it is a technology.

On the other hand, if the robot is a team member with a separate role in the team and making a unique contribution to its operation, then it is an agent-member of the team (Larson, 2020). Larson writes about four perspectives and roles that technology plays in leadership. We are now at a point in history where the technologies we work with are beginning to be treated as a teammate. In the first three perspectives, the role of technology is observed from the point of view of its impact on teamwork. In the most recent perspective, we look at technology not as limiting or extending what people do, but as acting as an equal member of the team (Larson, 2020).

The cooperation of humans and intelligent machines is a reality. What may need to be redefined is how to create and manage teams composed of humans and robots (or artificial intelligence algorithms). The purpose of this article is to illuminate the importance of the topic of cooperation of humans and intelligent machines. To indicate, based on the literature, what are the sensitive areas of such cooperation. Their identification, knowledge and understanding may prove crucial for the development of work teams, which are to be based on the teamwork of humans and intelligent robots or systems.

2. Method

The paper uses a theoretical (non-empirical) approach. A literature review was conducted to identify the state of research on areas affecting the cooperation of humans and intelligent machines within work teams. Such a review provides a good understanding of the issues of the research area and its results, current theoretical thinking and definitions. The information and conclusions presented in the article, are derived from the conducted literature review based on Scopus and Web of Science databases. The theoretical study was conducted in three stages. During the first, a search of the Scopus database was conducted according to the keywords: human, robot, team. Keywords were searched in the content of the texts of articles, in titles, abstracts and declared keywords. A search of the Scopus database by the words: human, robot, team resulted in 3530 documents. To narrow the search area, it was decided to limit it to the time interval: 2021-2017 and to the area: business, management and accounting . After narrowing the search criteria, 26 texts remained. To verify the results, an analogous search was conducted in the Web of Science database. The first iteration yielded 2783 results, after narrowing to the time period (2021-2017) and area: management, 13 texts remained. Articles found in both databases, were compared. In the Web of Science database, among the 13 searched texts, 11 overlapped with the texts found in Scopus., they were the same articles. Two articles found exclusively in Web of Science were included in the review of texts found in the Scopus database. A total of 28 texts were analyzed.

3. Results

A team is a group of people working together to achieve a specific goal. Working collectively is only possible when the individual efforts of each person are coordinated (Frame, 2001). A team is also defined as: a small group of people with complementary skills, presenting a common approach to work, genuinely committed to working toward a common overall goal and specific objectives for which they all feel responsible (Katzenbah, 2001). A team, is much more than a group of people working together. Because a working group is a group that works together mainly to exchange information and make decisions, aiming to help each other achieve the results that are within the responsibilities of each member. In working groups, their results are only the sum of individual contributions. Teamwork, on the other hand, produces a synergistic effect when the contributions of individual members result in an outcome greater than the sum of individual work contributions (Sapeta, 2004). The current definitions of a team, available in the literature, include the "human factor", not including other "entities". At the same time, the mentioned definitions emphasize the aspect of the contribution of work, competence or knowledge, of individual team members, in order to achieve goals and develop synergies. Such an understanding is in line with the assumptions made by Larson, that we can talk about machines as team members when robot-agents, make unique contributions to the teams in which they function. It is important to understand when there is human-robot interaction and when there is collaboration. Castro points out that interaction is when two or more people communicate and respond to each other. While collaboration, is when individuals work together to create or achieve the same thing (Castro, 2021). In the work of Ajoudani, a new definition of physical Human-Robot Collaboration (pHRC) is introduced: pHRC is the moment when human(s), robot(s) and the environment come to contact with each other and form a “tightly coupled dynamical system to accomplish a task” (Ajoudani, 2018). Ajoudani also highlights the distinction between Human Robot Interaction (HRI) and Human Robot Collaboration (HRC). In the latter, there is the realization of a common goal pursued by both the robot and the human, working together. In the case of HRI, the joint realization of the goal does not have to occur, the interaction may be limited to coexistence. Therefore, it seems appropriate to make efforts to better understand the processes of this new type of teams. Several challenges can be identified related to the increasingly rapid robotization. First: implementation requires organizational change, and second: employees may be hesitant or resistant to the change. Robots can support humans in many tasks, but this requires trust and cooperation from the operator. Third: increased robotization affects the workforce and leads to fears of job loss, thus negatively affecting employee motivation. Leaders must find ways to optimize the interaction of digital technologies and humans (Lambrechts, 2021). The human ability to accept robots in a team will finally determine the robots' success or failure as team members. Although the technical capabilities of robots, in terms of engaging in coordinated activities, are improving, the inherent human expectations of team-appropriate behavior create challenges for human-robot teams. They cannot be solved only by technological innovation (Groom, 2007).

4. Human Robot Interaction - Relevant Areas

Interaction between humans and robots is referred to in the literature, as Human Robot Interaction (HRI) or Human Robot Collaboration (HRC). Interaction (HRI) and collaboration (HRC) can often be confused with each other, or even seen as exactly the same item. Since HRI and HRC symbolize relatively new fields of research, there is not yet a global and absolute definition of the two terms (Castro, 2021). Research into behavior, or the reactions that occur between humans and robots, will require multidisciplinary work. Groups of researchers from fields such as robotics, cognitive science, psychology, social and behavioral sciences, among others, are needed. Interdisciplinary coordination is a prerequisite for successful research on interactive human-robot systems, e.g., developing roles for robots and humans in teams, learning about the adaptability of human-robot teams depending on the dynamic nature of the situation (Burke 2004). From the analysis of the literature, presenting the results of research conducted to this date, key areas that can be considered sensitive in the formation of human-robot cooperation emerge. They are shown in Figure 1. Probably, this list is not closed.

This article focuses on those few of the listed areas that, according to the authors describing them, seem to play key roles in shaping human-robot interaction, namely: trust, reliability, predictability, mental models and the influence of human and robot personalities.

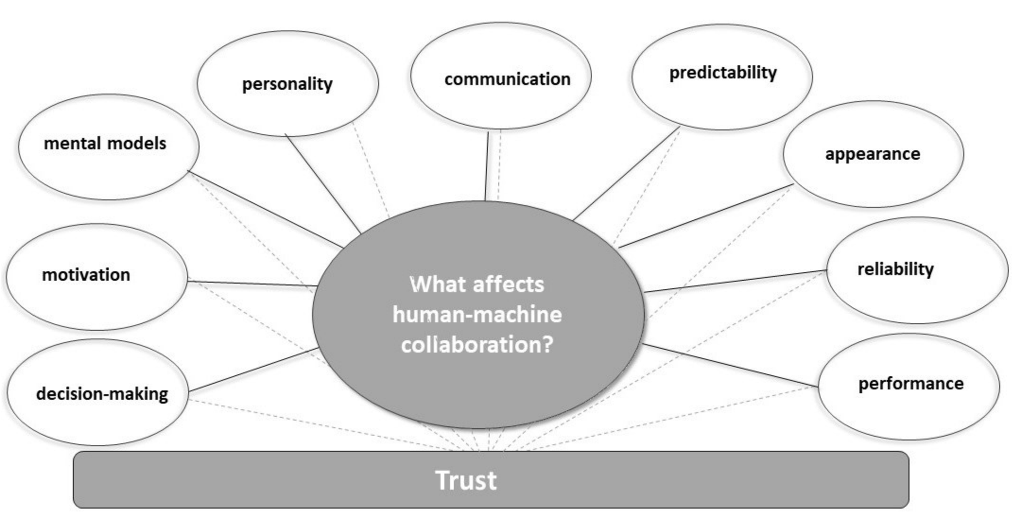

Figure 1. Important areas in HRI
Source: own elaboration.

Available research on trust in human-machine teams has focused on the perspective of the trust that artificial agents have with end users. Often neglecting other stakeholders' trust in the system or agent (Huang, 2021). Researchers point to treat trust in HRI teams as a distributed, networked state. Huang proposes framing trust in terms of Distributed Dynamic Team trust (D2T2). The model takes into account both interpersonal and technical factors related to trust in a human-robot team. The author believes that as the size and composition of the team changes, people's trust in artificial agents is spread across all related stakeholders. Thus, the attitude of each stakeholder, the team members, toward the artificial agent can play a role in shaping team trust. According to Huang, it is important to remember that trust in a team can change, either through direct interactions between humans and robots, or indirectly through the influence of others' opinions. Trust should be viewed as a dynamic process that changes and fades over time, sometimes rapidly declining, as a result of dynamic interactions between team members (Huang, 2021). Trust also establishes behavioral expectations that facilitate joint action. In high-risk situations, trust becomes even more important. Robots are often designed to replace humans in dangerous situations. This is when human trust in machines will be particularly important. As Groom, if robots are to succeed as members of a team, then in hazardous situations people must trust that other team members are capable of protecting their interests. (Groom, 2007). So what are the factors that increase the level of trust? Simon cites three: appearance, performance, proximity. Simon emphasizes that the appearance, or more specifically, the anthropomorphism of robots is a critical dimension affecting interactions with humans. For humans, it plays an important role for a robot to have a shape similar to the human body. Participants in the experiments cited by the author, pointed to the robots' heads and arms as elements in their design that would not only enable them to perform tasks, but also facilitate communication. At the same time, Simon mentions the uncanny valley phenomenon described by Mori. When it was proven that a moderate degree of robot's resemblance to a human, affects a significant sense of security. However, when the machine becomes too human-like, it begins to create a sense of strangeness and even terror in humans. In the triangle presented by Simon, proximity, understood as the physical distance between workers and the robot. People tend to place more trust in robots that are co-located. This can be correlated, with a sense of control that is strong in people interacting with robots. This will be discussed below, when describing the predictability of behavior factor. An important element of building trust, it turns out, is also the performance, reliability of machines. When humans are unable to predict what the robotic system is supposed to do, and when the robot's reliability decreases, human trust in the artificial agent decreases (Simon, 2021). Sanders also points out the importance of design elements (i.e., appearance) and features of the robot, in forming trust in HRI. A robot should act as a human expects it to. The anthropomorphism and personality of a robot can evoke a sense of comfort, especially when the appearance and behavior are tailored to a specific task. A robot's appearance also affects whether people perceive it as helpful or threatening, for example (Sanders, 2011). In the area of productivity, findings from experiments confirm that it is crucial for humans to have control over robots. A wide range of tasks can be delegated to robots or performed jointly by humans and robots, as long as human workers have the ability to supervise the robots' actions and intervene when necessary. The sense of being in control of the situation and having control over the robot is seen by humans as a facilitator of trust. Experiments conducted with a team consisting of astronauts and a humanoid Robonaut, revealed the importance of human stress as a factor affecting perceptions of robot reliability. When a human-robot team works in a situation without much risk, humans can better tolerate errors in, for example, robot communication and don't have to worry about whether the robot is a full member of the team. However, when humans have to rely on robots for their lives, the consideration of whether a robot is a full-fledged team member comes to the fore (Groom, 2007). This is because human co-workers, in a critical, stressful situation, have to additionally deal with diagnosing the robot's problems as well - if it turns out to be unreliable. Such situations will definitely reduce the level of trust in the machine. Also correlated with reliability is the area of control and predictability of machine behavior. In order to build trust, as well as to strengthen it in teams consisting of humans and robots, it is necessary that the actions of machines are predictable and follow a set pattern. Machines should be subordinate to humans and follow orders. Robots are programmed to act in a certain way. When situations deviate from the script, they may not know what to do. (Simon, 2020). A robot may fail to perform a routine task or react in an unexpected way to an unusual situation. When the stakes are high, even if the machine's actions do not put people at immediate risk, unpredictability will be perceived as a threat to the group's safety. The reciprocation of expectations triggers an upward spiral of team success, while the failure to meet expectations initiates a downward spiral of trust (Groom, 2007). It is also worth to mention, that one of the most difficult management challenges in HRI teams, will be on performance appraisals. A. Arslan points out that inquiries carried out in the area of computer games, have highlighted the need to take into account the issue of human limitations, especially the element of fatigue, in evaluating the performance of HRI teams. Organizations will be forced to develop a relatively fair performance evaluation system to keep human employees motivated and willing to continue interacting and collaborating with AI-equipped robots (Arslan, 2021). A factor observed in the literature that determines the effectiveness of an HRI team, in addition to trust, is the team's recognition of the same mental model. Two aspects of the existence or creation of mental models in HRI teams are of interest: whether the machines in such teams are able to produce a team mental model together with people, and what conditions must exist for this to happen. A team's mental model takes a form similar to an individual's mental model. Each team member can infer the basic motivations, perceptions and weaknesses of other team members from the model. The ability to infer the mental models of others allows people to develop a team mental model with a common set of goals, strategies and motivations. Sharing a mental model supports decision-making, communication and collective action (Groom, 2007). Mental models do not perfectly present reality, as information is filtered and changed by people to fit, for example, an emotional tint. Models help us to function efficiently, but are often complaint by our individual or group thinking. If we consider that robots by definition do not have mental models, this means that they do not need to filter information. At the same time, machines are designed with the ability to store and analyze data. Thus, processing information without mental models allows machines to evaluate information without the influence of moods or emotions. In high-risk, emotionally charged situations, a robot's ability to process all information without the influence of attitude, mood or emotion can enable it to process and make decisions more accurately (Groom, 2007). Teams with autonomous agents, are defined as teams in which humans and agents work together to perform tasks. The formation of a shared mental model in human teams is observable. It is therefore of interest whether it is possible, and if so, how to provide a human-robot team with the ability to naturally communicate and jointly develop knowledge and create mental models. The robot must be programmed to understand the task, the human team members and the environment as a whole. If a robot is not programmed in this way, it will not understand the knowledge that is shared, nor will it be able to share its own relevant knowledge. Similar mental models of humans and robots are needed so that each agent can understand the other (Burke, 2004). A noticed factor, affecting cooperation in an HRI team, is the human personality and the perception of the robot's personality. As Burke notes, an interesting issue in HRI teams is the question of social relations. One aspect is whether and when social relationships are necessary. For example, a "lack of personality" in an agent (software or robot) may result in people perceiving it as cold, unfeeling or indifferent. If so, do these perceptions differ among specific groups of people? (Burke, 2004). Professor Robert Jr. has prepared a review of scientific papers on personality in human interactions and robots. The analysis looked at the results of 84 studies described in scientific articles. The results of the review were structured into 4 main areas: 1) human personality and the impact on interactions with a robot, 2) the impact of robot personality on interactions with humans, 3) similarities and differences in the personalities of humans and robots, 4) factors influencing the personality of the robot. The personality measurements that were used in the reviewed articles 86% applied the Big Five personality traits. The Big Five is a widely accepted model for describing personality in terms of traits. McCrae and Costa - the authors of the Big Five - argue that the universal structure of personality consists of five basic traits, specific dimensions of personality: extraversion, agreeableness, conscientiousness, neuroticism and openness to experience (Encyclopedia of Management). The first of the 4 areas discusses human personality and its impact on interactions with a robot. Extroverts tend to be more willing to interact with robots. They also show higher levels of trust towards these machines. People with high agreeableness performed better when reminded them of the task by the robot, while people with low agreeableness were more likely to let the robot come closer when doing the job. It was found that people with high agreeableness were more trusting of machines (Robert Jr. 2020). When analyzing the impact of the programmed "robot personality" on interactions with humans, it was noted that the researchers were not always able to accurately assess the robots' personality, based on the machines' behavior. It was perceived that the type of personality displayed by the robots directly and indirectly influenced the degree of fun and enjoyment people had by cooperating with the machines. Robots that are perceived as extroverted and socially intelligent had high levels of human acceptance. In another area, similarities and differences in the personalities of humans and robots were analyzed. Humans tend to prefer robots that are more like themselves. Matching human and robot personalities yields positive results in several aspects: it improves the quality of interactions, promotes positive perceptions of the robot, and leads to higher levels of engagement with the robot. Machines that presented a playful personality were seen as more socially attractive and smarter. In the last area, it was summarized that important to people were the way the robot moved, the timbre of its voice, whether it spoke in a male or female voice, whether it gestured, whether it turned its head when conversing, and whether it had a humanoid form. This form of machines, was preferred by people, due to the perception of greater control over the robot, greater friendliness, a relatively low degree of awesomeness and a higher degree of reliability. So are personality factors among those that should be significantly considered, when forming human robot teams? The above analysis indicates that not all of us will equally accept robots as teammates. Some will adapt to such a situation faster, but there will probably be some who will not accept the constant presence of a machine. How about designing robots tailored "personality-wise" to the members of the teams in which they are to be implemented?

5. Discussion

Robots, even those that perform their tasks independently, gain autonomy thanks to sensors that allow them to exchange data with the environment. In teamwork, it is this autonomy - the independence of these machines, in the process of performing tasks - that is important. They do not require human, uninterrupted supervision, and bring unique value. Thus, the field of Human Robot Interaction, which today seems to describe human-robot relations as if over the top, will soon be studying our everyday professional reality. Researchers recognize the need to analyze human behavior when interacting with robots in the workplace, robots have been designed from the robot's point of view. While this approach was appropriate in the development of existing hardware and software platforms, it is not team-oriented. We need to consider how robots and humans can form synergistic teams (Burke 2004). In economies focused on implementing modern technologies based on artificial intelligence, it is necessary to remember that automation or robotization does not end with the introduction of smart machines into a company. The task of creating HRI teams in organizations will be the responsibility of the managers who will manage such teams. Whether the new type of teams will be a satisfying place for people to work will depend largely on the competence of the managers. Lambrechts notes that one of the most important, and most difficult, goals is the acceptance and willingness of people to engage with HRI teams. Character, motivation and proactivity are key factors in leadership during robot deployment. Team leaders can ultimately aid or hinder the process (Lambrechts, 2021). A deeper understanding of the processes involved in the new type of teams is expedient. An analysis of the literature on HRI shows two paths taken by researchers: one focuses on the engineering perspective: the development of robot capabilities, functionality, efficiency. But there is also a sizable group of researchers who pay more attention to human reactions, the psychological factors of human behavior. Robotization, or automation, or even more broadly the digital transformation of companies, should not be limited to the implementation of technologies, programs, devices, etc. It is important to be able to look at these processes from the point of view of caring for the well-being of the human worker. A great responsibility of managers should be seen in the implementation of this task.

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