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Fostering Human-Agent Team Leadership by Leveraging Human Teaming Principles

Christopher Flathmann
School of Computing
Clemson University
Clemson, United States
cflathm@clemson.edu

Beau G. Schelble
School of Computing
Clemson University
Clemson, United States
bschelb@clemson.edu

Nathan J. McNeese
School of Computing
Clemson University
Clemson, United States
mcneese@clemson.edu

***Abstract*—With human-agent teams beginning to enter the workforce, it is important that humans are well equipped to lead their future teams. Due to the addition of artificial intelligence to teams, the behavioral functions of leaders need to be critically examined to determine their fit with the future of human-agent teamwork. This paper identifies these functional behaviors as resource management behaviors and information behaviors based on past research in teamwork. These behaviors are reviewed within the context of human-human teamwork to define human-oriented leadership behaviors. Based on the review of human-human teamwork along with recent research in human-agent teamwork, an adaptable framework is created for leadership behaviors that will help guide human leaders in human-agent teams. This framework provides a foundation for future human-agent teams to empower and guide human leaders of human-agent teams who need to mediate the integration of agents alongside humans.**

***Index Terms*—Human-Agent Teaming, Leadership, Organization, Interaction Behaviors, Theoretical Framework**

I. INTRODUCTION

With the state and performance of autonomy improving every day, the eventual reality of humans and artificial intelligence (AI) agents working together in teams becomes more likely. This integration of AI agents has led to the rise of human-agent teamwork where humans work alongside artificial agents as active teammates that have their own roles, goals, and abilities [1]. This teamwork extends beyond simple human-automation teamwork, which is traditionally rigid, by creating flexible and powerful teammates that will both adapt to humans and require that humans adapt to them. This transition will also require attention to interactions that team members have, such as communication and authority [2]. As many modern teams begin to transition from human-human teams to human-agent teams, it is important to equip human leaders with the tools to lead their teams. These leaders will be responsible for ensuring efficient interactions between teammates, information, and resources. While it may be difficult for modern machines to become effective teammates, rather than basic tools [3], as AI technology advances the potential for AI teammates to more closely resemble human teammates will grow. Therefore, it is important to evaluate leadership in a human teaming context and see how this leadership can be empowered to extend to newly added AI teammates. If this empowerment is not done, then human-agent teams may not reach their potential as they will not gain the benefits from having an effective leader [4].

This paper creates a theoretical framework through the use of past and recent research to ensure the model builds on previous and important research while also demonstrating the framework's growing importance in society, which is esstential to making a relevant theoretical model [5]. This paper utilizes previous literature on leadership behaviors and human-agent teaming to design a leadership behavior framework that can be used by humans as they lead their human-agent teams. Four leadership functions have been identified by previous literature: (1) information search and structure, (2) information use in problem solving, (3) managing personnel resources, and (4) managing material resources [6]. To ensure effective leadership in human-agent teaming, this paper centers around the following research question: How do the behaviors presented by Fleishman et al. (1991) need to be modified to ensure they are effectively used by leaders in human-agent teams? This is answered by first elaborating on these leadership behaviors and the research surrounding them. Then, a new framework is presented that modifies these behaviors to better enhance human-agent teams. Finally, methods of implementing this framework are discussed and how these methods may be used by human-agent teams.

By using previously established research in human-human teamwork as a base, the framework of this paper is human-derived and usable by human leaders. Fleishman et al.'s (1991) model serves as base for leadership behaviors for teams, which can be extended and modified to be better designed for human-agent teams.

II. REVIEWING LEADERSHIP IN TEAMWORK

Since human-agent teams will include humans as both standard teammates and leaders, it is vital to ensure whatever frameworks are created are human-oriented and human-derived. Four main leadership behaviors have been identified in human-human teamwork. These behaviors include (1) information search and structure, (2) information use in problem solving, (3) managing personnel resources, and (4)

managing material resources [6]; however, due to the overlap of these four behaviors, especially in the context of human-agent teaming, this review is going to be organized into two broader review categories: (1) information management and (2) resource management. While leaders may not individually manage each piece of information or every resource, it is their responsibility to ensure both of these categories are managed and utilized by teammates in their human-agent team [7].

A. Information Management

While society is filled with countless amounts of general information with more being produced everyday, the basic aggregation of all data sources could be detrimental to teams as important information becomes buried by unimportant or even incorrect information. This information generally consists of ideas, concepts, and results which can be freely passed and shared without limitation. As such, it is vital that a team's access and use of information is done efficiently with the help of team leaders. Of the categories identified by fleishman et al. (1991), the factors important to information management are (1) the actual search and structuring of this information and (2) the use of this information to solve problems. While leaders do not directly conduct this search and use of information, their function is to guide their team and ensure information is being gathered and utilized.

Information search and structuring revolves around a leader's ability to search for potentially relevant data, acquire the ability to use said data, evaluate the utility and importance of the information, and "[organize information] regarding team goals and operations" [8]. This data is not limited to information outside of the team but also information that the team creates itself and the data created by other teams in the same environment [9]. After this data is organized and structured, a leader is responsible for the "application of acquired information to problem solving in the service of the team goal attainment" [8]. These two areas are heavily intertwined, as poor structuring of data could lead to ineffective use and poor use of data could lead to worse search and acquisition later on. To ensure the relationship between these two concepts is not only preserved but empowered, the collection of feedback becomes a mechanism for the effectiveness of not only their team but the leadership behaviors they are practicing [10]. While feedback increases the information complexity of a team, its utility for not only leaders but other team members makes it a vital information channel. These two divisions, the search of data and the use of data, contribute to the overall picture of the utility of information to team performance and how the simple availability of information is not enough for a team to be effective. Teams, and for that matter leaders, need to ensure that this information is utilized [4]. Information management creates unique behaviors for leaders, but these behaviors are still further enhanced by behaviors in resource management as the use of these information resources will not be possible without the proper personnel and physical resources to utilise them.

B. Resource Management

In addition to information management, one of the key leadership behaviors that contributes to team effectiveness is resource management, or the intentional use and organization of resources to accomplish a team's goal [4], [8]. Unlike information, resources are generally finite and material, which results in the management of them requiring a much stronger focus on scheduling and assignment. Similar to information management, resource management can be broken up into two main subdivisions: (1) physical resource management, and (2) personnel resource management [6].

The organization of people needs to accommodate for a variety of factors such as competencies, preferences, knowledge, skill, and experience [11]. This organization becomes difficult as every team member will have a different combination of these factors, so it takes a very skilled leader to effectively organize these teams. This complexity in personnel management directly impacts the management of physical resources as each team member could have completely different preferences and requirements for what physical resources they need [12], which could lead to disputes about resources. If these disputes between team members occur, then it is a leader's job to step in as a mediator and reorganize their team [13]. While attempts are made to create self organizing teams through modern methodologies (e.g. agile), a central leader for organization still tends to emerge and facilitate the organization of physical and personnel resources within the team [14], [15]. These instances of self-organizing teams show how even with distributed leadership in modern teams, these leadership behaviors are still required for team effectiveness.

C. Interactions Between Managing Resources and Information

In addition to the subdivisions of these two areas having a large amount of interdependence, these two larger divisions also interact with each other regularly. For instance, factors used to organize personnel, such as knowledge, skills, and abilities (KSAs), would contribute to the shared knowledge of a team as a whole and would additionally be managed by behaviors in information management, through systems such as transactive memory systems [9], [11]. While literal information is not a physical resource, the means for acquiring it could be, whether it be from people or the environment, leading information organization to have overlap with resource management. These two divisions will become more intertwined and interdependent as agents, which can be viewed as both a physical and a personnel resource, begin to produce, require, and acquire large amounts of information to effectively function as teammates. As AI agents, which have traditionally been identified as machine resources, begin to become personnel that generate and utilize a large amount of team information, it is important for leaders to be well equipped to utilize their human-human team expertise in a human-agent context.

III. Leadership for Human-Agent Teams

To ensure that leadership in human-agent teams is human-oriented, it is necessary to use the previously outlined research in human-human teamwork as a foundation for behaviors of leaders in human-agent teams. While agents are playing active roles in these teams, frameworks for these human-agent teams still need to focus on being human-centered.

A. A Framework for Human Leaders

While the framework in Figure 1 utilizes the two main categories of resource management and information management, the way these categories manifest has been changed to accommodate the integration of agents. A connecting action has been created to allow for the natural and promoted interaction between resource and information management, and important factors in each category have now been brought out due to their increased importance in human-agent teamwork. This framework has also been designed with a modular approach where uses of this framework can utilize context specific methods as they are not dependent on other factors in the framework. The methods can easily be switched in and out as long as they have the same goal of serving their derived category. It is important to note that this framework allows for the other resource management behaviors to affect information management and vice versa. Due to the connection between information management and resource management, individual behaviors are allowed to affect each other and do not exist in a vacuum [4]. This interaction creates a more dynamic and less rigid system that adjusts to decisions leaders make. Overall, the framework is flexible enough to adapt to a variety of contexts, promotes collaboration between leadership behaviors, and is most importantly human-derived. Similar to the previous literature, this framework is broken down and discussed in regards to three main topics: (1) resource management in human-agent teams, (2) information management for human-agent teams, and (3) the connected behavior of organization between these two categories.

B. Leading Resource Management in Human-Agent Teams

The integration of agents creates a unique challenge in resource management since agents are computational resources, but due to autonomy, these computational resources can become active teammates. While behavior of physical resource management exists in this framework, it looks contextually different than in human-human teamwork. Physical resource management is inherently tied to AI as they cannot exist without the proper physical resources. Managing physical resources will still need to exist as a leadership behavior, but it must change as artificial teammates will be included in this category. Due to the computational nature of agents, their management properties such as scheduling would be heavily reliant on their availability of physical resources. While managing these resources can be difficult within one's own team, this scheduling becomes more complex as more teams being to share agents. Leaders will need to collaborate with other leaders and their own teammates to schedule the use of these resources and agents. There are also possible avenues for using other agents to moderate these management behaviors [16]; however, to ensure that these agents are still acting with the humans best interests, teams should retain at least one human in a leadership role.

Unlike physical resources, managing personnel resources needs to be separated into the vital behavior of motivating humans along with the connecting behavior of organizing a team [4]. Since motivation will not be required for agents, this has been separated from the other behaviors to signal its prioritization and distinctness. Two primary methods for motivating human teammates includes empowering them with AI agents and providing teammates with meaningful feedback to help guide them. As AI teammates become more common, ensuring that they are used to empower human teammates, and it is the leaders responsibility to ensure that these agents are used to empower and motivate humans. Feedback has been shown to be vital in motivating humans [4]. As humans transition roles and adapt to AI teammates it is vital for leaders to provide feedback as a motivation tool to help this transition. As this would only involve motivating humans, humans should be the only ones utilizing this behavior from a leadership perspective.

C. Leading Information Management in Human-Agent Teams

While resource management is vital to leading human-agent teams, so is information management. Each piece of the information management division has been modified for human-agent teamwork. First, leaders need to be able to mediate information between humans and agents. As previously mentioned, one of the hardest challenges facing human-agent teaming is communication [17], so it is imperative that leaders do everything they can to prevent negative effects from these deficiencies. When these deficiencies in communication are overcome, human-agent teams are able to significantly increase their effectiveness [1]; however, since this is not possible with current technology, it is vital that leaders actively mediate this communication. This mediation involves multiple tasks including: (1) gathering information for their team to utilize, (2) determining what information should be given to humans or agents, and (3) mediating the share of information between humans and agents. This is a prime example of why humans still need to be leaders as they need to be the ones mediating conversation between humans, agents, and other teams, which would be difficult with an artificial leader with communication deficiencies.

In addition to mediating shared information, the direct use of information becomes more intensive and important in human-agent teams due to the data requirements of artificial agents. One area of information that is given increasing priority in human-agent teaming is feedback, as autonomy's key strength is being able to independently react and learn with feedback. To utilize these features, large shared information resources will need to be created to provide agents with a variety of data sources [18]. As resources grow and teams begin to produce more data, agent teammates will become more

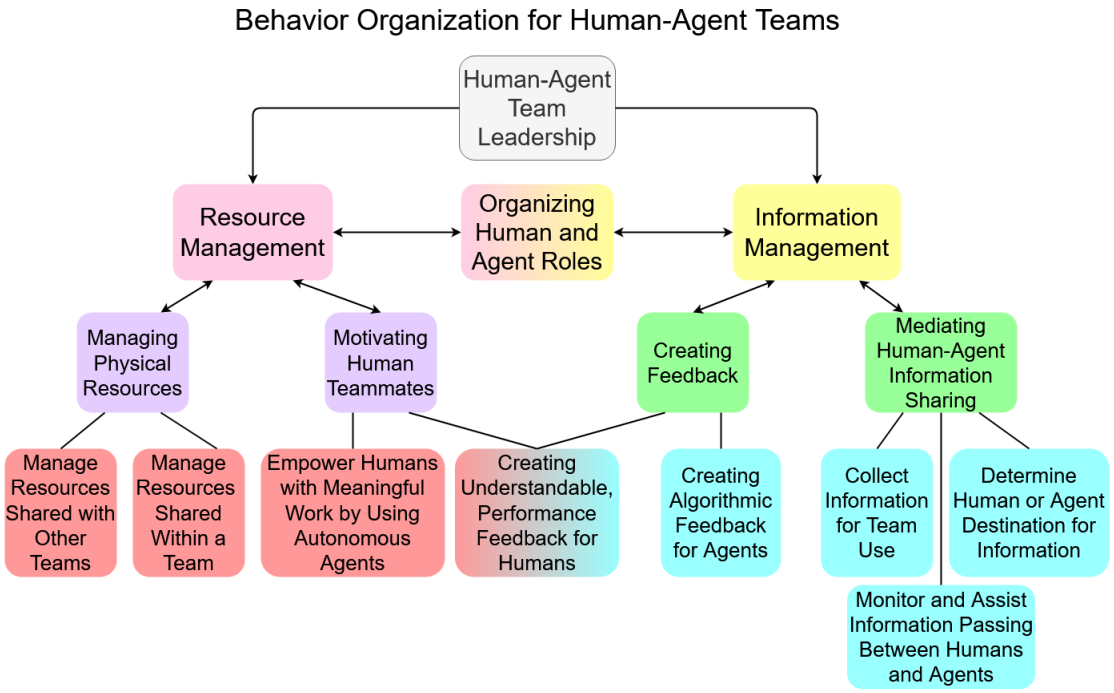

Fig. 1. Adapted from [6]. An organization of leadership behaviors and how they will manifest in human-agent teams. Modifications and changes were made from human-human literature to allow interaction between information management and resource management in addition to accounting for the interaction of agents.

intelligent and context aware. While algorithmic feedback for agents is important, it is imperative that human feedback is still given. As previously mentioned, human feedback will be vital to ensuring an effective transition from human-human to human-agent teaming. This feedback needs to be heavily rooted in the information the teammate is using and creating.

D. Connecting Resource and Information Management through Organization

One of the most important aspects of this framework is the behavior of organizing agents and humans in a shared and common environment. With the integration of agents, the importance of creating roles specialized for both humans and agents will become vital, and organizing these roles to utilize each other will be key to creating successful human-agent teams [19]. As agents continue to increase in prevalence and large scale systems are created, organizing groups of these agents to interact with humans will become both more complex and more vital, making it necessary for leaders to prioritize organization as a leadership behavior [20].

While these agents exist as both personnel and physical resources, they also drastically change the information landscape of a team. The introduction of these agents can drastically change how teams are organized and how information gets organized. Since agent roles are entirely dependent on the information available to a team, minor changes in either information or resource management could drastically affect the other category. As such, it is vital that organization exists as both a resource management behavior and an information management behavior to mediate the interaction between leadership behaviors in these two areas. With other challenges facing the coordination of agents, such as communication, leaders will need to constantly prioritize the organization of their teams using both human factors, computational factors, and information management behaviors. Human leaders will need to utilize all outlined leadership behaviors to organize their human-agent teams.

IV. Discussing Human-Agent Leadership in Context

One of the key aspects of the framework presented is its modularity at the application level, allowing for application to a variety of different contexts. Each element has the ability to not only adapt but change during implementation if properly planned by a leader. This section will evaluate this modularity, provide real world examples of what this modularity will look like, and discuss the potential of automated leaders under the supervision of human leaders as a type of method implementation. While this framework has focused on the use of humans leaders, and will continue to due so, it is also important to acknowledge the potential for agents to aid in the leadership process.

A. Changes Between Contexts

One of the primary goals of this framework is to be applicable to a variety of human-agent teams as multiple different industries begin to integrate agents. This is important as the applicability of human agent teaming can be seen in

a variety of different contexts, including military [21]–[23], manufacturing [24], [25], and medical [26], [27], and many of these contexts also require interaction with other contexts, where understanding leadership differences would help these cross context interactions [28], [29]. A good example of how this could look different, yet similar, from environment to environment, would be in the management of physical resources. For instance, in medical environments, the availability of physical resources and equipment can have effects on team performance due to the time sensitive nature of many situations and interactions in the environment [30]. In this instance, AI agents may be viewed as more of a physical resource due to the importance of scheduling and maintaining availability due to the dynamic environment. While medical environments might prioritize specific factors within this category of physical resource management in regards to the use of agents, they are still prioritizing for resource management. However, if an environment such as unmanned aerial vehicles (UAV) is examined, large contrasts can be made with the medical environment despite still prioritizing the same behaviors. The use of agents in a UAV environment would see them as active teammates [1] so scheduling their availability may relate more with the scheduling of humans, rather than machines, though these teams are still managing their physical resources. In this context, the physical resources of the agent would still be integral to the team, but the perspective the team takes would be much closer to a personnel management approach.

Due to the intertwined relationship between leadership behaviors, completely ignoring a behavior could have negative side effects. For instance, if a UAV command system were to completely ignore scheduling agents as a physical resource, then they may run the risk of not having the proper computing resources or agent availability when they need it, which would in turn affect the team organization along with other behaviors indirectly. However, if leaders are able to properly manage these agents from a physical perspective, human teammates may see them less as machines and more as teammates due to not being impacted by physical limitations. This is but one example of how neglecting a single behavior could negatively affect a team; however, if leaders utilize the created framework, then human-agent teams can be intentionally guided and effective.

B. The Possibility of Utilizing Agents for Leadership Functions

While this framework focuses on human leaders in human-agent teams, there is potential to integrate AI teammates to help assist the leader, but not replace them, by conducting specific tasks that are generally more administrative and repetitive [31]. An example of where an agent could be beneficial is in the organization of teams as more agents are utilized and the type and amount of roles covered grows. By allowing agents to coordinate other agents, the organizational load on the leader would be reduced [19]. Additionally, the agent could organize goals for both the team and individuals [16]. Both of these processes would require similar yet uniquely different intentions and behaviors when being done. Agent leaders would need to have a clear understanding of worker agents' abilities, roles, availability, and current task priority. This is also an example of where information management is still an important factor in leadership, even if resource management is the main focus. On the other hand, organizing goals for human-agent teams may require a much stronger emphasis on information management. Agent leaders would need a strong understanding of not only worker agents' abilities but also human abilities, which would allow optimal goal assignment.

The same could be said for managing physical resources where agents would be in charge of scheduling, a fairly mathematical task and ideal for an agent. While these two areas could benefit from the utilization of artificial agents, an area such as mediating human-agent collaboration shouldn't be integrated with autonomous leadership. Since a leader needs to ensure agents are effectively communicating, humans would be necessary as deficiencies in communication could affect multiple agents and prevent proper mediation. This area would require human expertise to moderate as failures in communication would be detrimental to the entire team. By integrating these artificial "leaders" as methods it would still allow human leaders and teammates to continue to manage the agent, while also helping alleviate the cognitive load on some leaders. Overall, there is potential for agents to be integrated into these leadership behaviors but less as leaders and more as methods for the behaviors. Artificial leaders are but one example of how the behaviors outlined in this framework could be implemented; however, it is up to human leaders to determine the best implementation for their team as they will be responsible for the interaction of these behaviors.

V. CONCLUSION

While human-human literature provides a good foundation for leadership behaviors that will help team effectiveness, these behaviors alone are not enough to lead human-agent teams. This paper identifies these behaviors and extends them into a framework catered towards human-agent teamwork. While this framework specifically focuses on human leaders in human-agent teams, it also prioritizes the flexibility to be integrated in a variety of contexts. This framework serves as a foundation for current and future human-agent teams to ensure human derived leadership behaviors are consistently prioritized while still allowing humans, agents, and human-agent teams to efficiently function.

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