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Is It Human or Is It Artificial Intelligence? Discerning the Impact and Effectiveness of Process Managers Based on the Manager's Identity

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Abstract

This work studies the perception of the impacts of AI and human process managers during a complex design task. Although performance and perceptions by teams that are AI- versus human-managed are similar, we show that how team members discern the identity of their process manager (human/AI), impacts their perceptions. They discern the interventions as significantly more helpful and manager sensitive to the needs of the team, if they believe to be managed by a human. Further results provide deeper insights into automating real-time process management and the efficacy of AI to fill that role.

Keywords: artificial intelligence (AI), design management, design teams, problem solving

1. Introduction & Motivation - Why Study Human-AI Teams

With the accelerating developments and investments in machine learning, artificial intelligence (AI), and digital technologies, understanding human-machine collaboration is becoming more critical than ever. Research has shown that AI-assistive technologies can significantly improve problem-solving and learning outcomes. These benefits have been instrumental across a variety of domains and applications, such as instructional agents in educational tutoring (Roll et al., 2014; Hu and Taylor, 2016), design problem-solving and in exploring complex design spaces (Camburn et al., 2020; Koch, 2017; Schimpf et al., 2019), cognitive assistants (Graesser et al., 2001; Costa et al., 2018), and in the facilitation of collaboration (Dellermann et al., 2019; Gunning et al., 2019). Ginni Rometty, the Chief Operating Office of IBM, argued at the 2017 World Economic Forum (Lewkowicz, 2020) that instead of fully replacing humans, AI should be meant to *augment* humans, thus setting the stage for human-AI hybrid teaming (Sadiku and Musa, 2021). Leveraging this type of collaboration, human and AI agents can take advantage of their complementary strengths, partnering the computational and analytical powers of AI with the creative, empathetic nature of humans (Lake et al., 2019; Dellermann et al., 2019). However, if the goal is to create more powerful human-AI teams, humans must have appropriate amount of trust and reliance in these agents that are meant to augment them.

Considerable research in human-computer interaction focuses on individuals' trust in AI machines and computer systems (Hoff and Bashir, 2015, Ezer et al., 2019; Lee and See 2004). There exist different types and definitions of trust, and trust is certainly a complex phenomenon that can change dynamically over time (Hoffman et al., 2013). As social agents ourselves, the more "human" a fellow agent becomes, the more we trust and comply with them (de Visser et al., 2012). Even though trust is not directly measured here, these themes have direct implications in this work, in that whether a person believes they are working with a human versus an AI may affect their reliance on input or guidance from that agent. Our work studies a unique intersection of human-computer interaction and

engineering design - AI as a real-time process manager for design teams. Thus, how these interpretations of trust and reliance are navigated will impact the design of future human-AI hybrid teaming in design.

Prior research by the authors has worked in the area of human-AI hybrid teaming. Leveraging the finding that process management brings tremendous benefits in aiding team problem solving (Gyory et al., 2019), this current work brings in an AI agent that augments human teams through a novel managerial role (Gyory et al., 2022). In this work, a crafted AI agent oversees the problem-solving processes of engineering designs teams, in the context of a complex, interdisciplinary drone design and path planning problem. Individual team members do not have access to all the required information and must efficiently communicate and collaborate with the rest of their team to succeed. The process manager agent tracks real-time team behaviours during problem-solving and intervenes at discrete points in time to facilitate the team process. The main goal previously was to study the impact and intervention strategies of the AI process manager and compare them to that of human process management. While not a true deception study (i.e., teams were not told that they would be human-managed or AI-managed while being managed by the other), this current work takes advantage of the questionnaire data from that study. The questionnaire data includes questions related to the effectiveness of the process manager and the interventions received, as well as the perceived identity of the manager (human or AI). This data presents the opportunity to learn how members perceive this process management based on their belief about the identity of the manager. Thus, this current paper presents two main goals. The first objective studies the process manager's effectiveness based on the team members' perception of the identity of the manager. The second objective seeks to better understand the distinctive differences between the two types of process managers. While trust is not directly measured here, these objectives certainly bear implications for future research in that area, and in tandem, guide the further development and deployment of AI process managers to augment human design teams during complex problem solving.

2. Background - Previous Process Manager Study

The analyses in this work utilize data from a prior process manager study. This section describes details of this study as relevant to the above two specific research aims. More exhaustive descriptions related to the experimental design, the collaborative research platform HyForm, and the underlying computational framework of the AI process manager can be found in published work (Gyory et al., 2022).

2.1. Experimental Design

Via a large-scale human study, 199 student engineers participated and were randomly assigned to one of two distinct team conditions. Each team consisted of five interacting team members and one process manager. The two experimental conditions were defined by the identity of this process manager, which was either a human or an AI agent, and never known to the team members. These process managers were not part of the interacting team itself but external to the team, as they could not directly communicate with the team or assist in directly solving the problem. Instead, the managers intervened via a set of prescribed interventions to facilitate and redirect the problem-solving processes of their team. Completed fully online via the collaborative research platform, HyForm[1], the team members communicated with each other through text-based channels within the platform.

HyForm simulated a complex and interdisciplinary drone design and path-planning problem (Song et al., 2022). The teams' goal was to maximize their overall profit. Each team consisted of three distinct roles: two drone designers, two operations specialists, and one problem manager. The drone designers designed drones by configuring different components such as wings, batteries, air foils, rods, and nodes to attain different drone velocities, distances, and capable payloads. Once designed and submitted by the design specialists, the operations specialists selected from the drones, created drone fleets, and planned delivery paths within a selected customer market. Teams gained profit by successful parcel and food deliveries. Once a delivery plan with drones and paths was generated, the

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[1] "HyForm" GitHub. https://github.com/hyform/drone-testbed-server/releases/tag/2021-March-v2 (March 2021)

problem managers collected these and submitted the best plans of their team. The problem managers also played a communication-bridging role. For the drone designers and operations specialists to communicate with each other, they had to communicate through the problem manager, adding another layer of complexity. Requirements, constraints, and sub-tasks were distinct and specific to each discipline and needed to be communicated across disciplines. Thus, to effectively accomplish their overall objective, teams must have effectively communicated and collaborated with each other.

The entire experiment consisted of two 20-minute, problem-solving sessions. During these sessions, the teams worked on their delivery plans (i.e., drone designs and delivery paths) and received interventions from the process managers. These interventions were not meant to intervene in directly solving the problem, but to help the teams' process (e.g., getting team members to communicate with each other more, redirect problem-solving efforts, etc.). After the experiment, the teams completed a post-study questionnaire. The questionnaires were different for the team members versus those for the human process managers. The questions for the team members focused on their thoughts regarding characteristics of the process managers, the interventions they received, and their teams' performance. Questions for the human process managers related to their teams' performance and their intervention strategies.

2.2. Process Managers - Artificial Intelligence Agent and Humans

Two types of process managers guided teams - either a human or an AI agent. As mentioned, these process managers (note, this role is different from the problem managers) could not communicate with the teams except through a prescribed set of interventions. The AI process manager agent took a data-driven approach to management while the human process managers took an observational approach. In other words, the agent provided interventions based on an underlying, decision-making process while the human managers provided interventions based on their observation. Regardless of this identity, both process manager types tracked the same types of real-time, team behaviours. This included observing aspects of team communication and actions team members performed in real time. HyForm tracked all communication amongst the team and each individual action taken by a team member. In this way, HyForm captured the entire problem-solving process of the teams, and it was this information the process managers used to determine what to intervene with.

HyForm allowed the human process managers to observe these team behaviours and intervene in 2.5-min intervals throughout two problem-solving sessions. The process managers could only intervene at these distinct points in time. Accordingly, teams received up to 12 interventions from their process managers throughout the entire experiment. To minimize extra variability within the experimental design, the managers chose from a pre-defined set of specific interventions, motivated from the previous experiment run in HyForm (Gyory et al., 2022; Gyory et al., 2021). Table 1 shows the complete set of interventions, and to whom on the team they were targeted towards. Both process manager types chose from this same set of interventions shown in the table, and once selected, these interventions were presented to the teams via the chat channels in HyForm.

In deciding which intervention to implement, the AI process manager compared the real-time characteristics of the team to previous, high-performing team data. This prior data was also collected in HyForm from a similar done design and path-planning problem (Zhang et al., 2021). The underlying algorithm the AI process manager used is as follows. The first decision compared the total team communication frequency with the total team action frequency. If both frequencies fell within +/- 1 standard deviation from the prior high-performing team data, then the AI would choose not to intervene (i.e., select none of the interventions from Table 1). Otherwise, the AI selected either an action-based intervention (the first six interventions in Table 1) or a communication-based intervention (the last six interventions in Table 1), depending on which one was most off course from the prior data. For the six action-based interventions, the AI analysed the cadence of different HyForm action categories (design refinement, design evaluation, and agent assistance). For the six communication-based interventions, the AI used natural language processing techniques to identify keywords and similarities amongst the team communication. The AI then made similar computational comparisons between the high-performing team data and the real-time team data to determine which one of the six action-based or communication-based measures was most off course, and thus the appropriate intervention. This comparison to prior team data created this data-driven approach to

process management. The human process manager had access to the same real-time team data but not the prior data, and thus, relied solely on their observations in real time.

Table 1. Prescribed set of process manager interventions (left) and whom on the team would receive each (right).

Intervention	Individual on Team
"Ops. planners, it would be good to continue working on and refining your plans a bit more."	Operations Specialist 1 & 2
"Hey operations team, I suggest that you try evaluating and submitting your plan and starting fresh."	Operations Specialist 1 & 2
"Hey operations team, try running the path-planning agent to help."	Operations Specialist 1 & 2
"Drone designers, it would be helpful if you can continue working on and refining your drone designs a bit more."	Design Specialists 1 & 2
"Hey drone design team, I would recommend evaluating and submitting your current design and starting fresh."	Design Specialists 1 & 2
"Hey drone design team, check out the suggestions from the drone design agent."	Design Specialists 1 & 2
"Team, I think you should try focusing more on adjusting the design parameters to meet the goals of the problem, and share this with each other (cost, capacity, speed, budget, weight, etc.)."	Operations Specialist 1 & 2; Design Specialists 1 & 2; Problem Manager
"Team, try focusing more on your strategy. Try optimizing and increasing/decreasing size of components and share this with each other."	Operations Specialist 1 & 2; Design Specialists 1 & 2; Problem Manager
"Hi team, try sharing your goals with each other a bit more and make sure they're aligned."	Operations Specialist 1 & 2; Design Specialists 1 & 2; Problem Manager
"Ops team, please try to communicate with each other more."	Operations Specialist 1 & 2
"Drone designers, please try to communicate with each other more."	Design Specialists 1 & 2
"Hi problem manager, please try to communicate with your team more."	Problem Manager

2.3. Post-Study Questionnaires

Following the experiment, all participants filled out post-study questionnaires. These questionnaires provided deeper insights into several characteristics regarding the interventions and the process managers. All five team members on the interacting team received the same post-study questionnaire, however, the process managers received a different version. While the team members were asked questions related to their team performance and aspects of the interventions they received, the process managers were asked if they felt constrained in the interventions they could provide and why/why not they intervened with their team. Only the questions from the questionnaires relevant to the research goals of this current work are covered here.

The relevant inquiries asked in the team members' questionnaires included the following:

1. *"How would you rate the quality/cohesion of your team?"*
2. *"Did you follow the interventions?"*
3. *"Did you feel that the interventions were relevant and helpful?"*
4. *"Was the process manager sensitive to the needs of the team?"*
5. *"Do you think that your team could have benefited from any additional interventions from the process manager? If so, in what ways?"*
6. *"Do you believe that the interventions you received were from a human process manager or an artificial intelligent (AI) process manager?"*
7. *"What characteristics of the interventions made you feel that way?"*

The first question queried participants about the performance of their team. Questions two through five queried team members on the interventions they received/did not receive. The final two questions

asked participants whether they believed the process managers' identity to have been a human or an AI agent. These final two questions were placed last on the questionnaire to not bias their answers to the previous questions (also, participants could not move back in the survey). It should be emphasized that at no time throughout the experiment did participants know who (human versus AI) guided their team process as the process manager. Moreover, at no time during the experiment did participants know that the identity of the process manager may be different or was even part of the research question.

On the process manager side, the applicable questions included the following:

8. *"What were some of the reasons you did/did not intervene with your team? Try to be as specific as possible."*
9. *"Did you feel constrained in the items you could intervene with?*
10. *"What else would you have liked to intervene with that you were not able to? Why?"*

These questions yielded deeper insights in uncovering what may have caused the human process managers to intervene when they did, and with what they did, and additional types of interventions that would be most appropriate for managing the team process generally.

3. Results

Previous work by the authors shows that the created AI process manager agent matches the capabilities of the human process managers, even trending towards marginally improved performance over time (Gyory et al., 2022). These similarities extend across a variety of dimensions including how teams perceived the relevancy and the helpfulness of the interventions, the sensitivity of the process managers to the needs of the teams, as well as general intervention strategies. In that work, results are split based on the team conditions: AI-managed teams versus human-managed teams. In this current work, results show team members based on their answer to question six from Section 2.3; whether they believed the process manager to be a human or AI agent, regardless of whether they had a human or the AI manager. In this way, even though trust is not directly measured, this new categorization of team conditions allows us to indirectly measure how teams respond to and regard the two types of process manager.

3.1. Perceptions of Team & Process Manager Effectiveness

To provide initial context for the analyses presented in this section, Figure 1 provides a basis for the proportion of team members that ascertain the identity of the process manager in a certain way. Overall, regardless of actual team condition in the experiment, approximately 75% of all team members believe the process manager to be an AI agent while 25% believe the process manager to be a human even though there was a near even split of team conditions (16 human-managed and 15 AI-managed teams). The succeeding results provide rationalizations for the existence of this disparity.
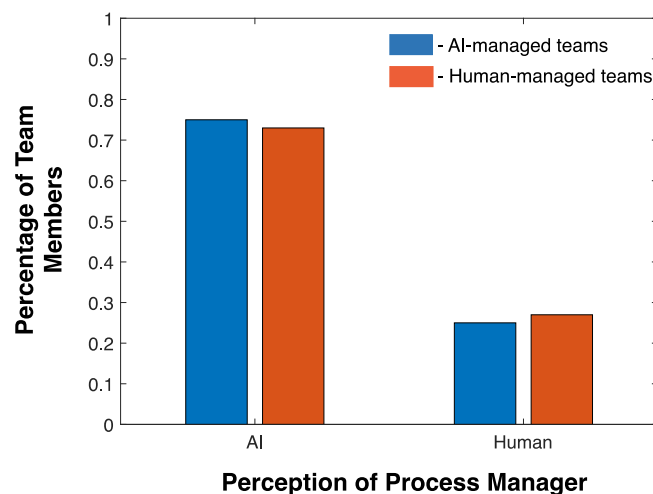
Figure 1. Percentage of team members who thought they were guided by an AI agent versus those who thought they were guided by a human process manager.

Figure 1 presents the extent of how team members perceived the identity of the process manager, the first analysis compares team members' perception of their team performance, grounded on this new separation of team conditions (i.e., those perceiving the process manager as human versus those perceiving the process manager as AI). On an interval scale from 0 to 100, with 100 being the best performance possible, team members rate the quality of the performance of their team and their team's cohesion, or how their team worked together. Figure 2A and Figure 2B show results based on those who perceived the process manager to be an AI agent and those who believed the process manager to be a human. The results indicate that the discernment of the process managers identity did not affect the way that members view their teams' performance (p = 0.2) or cohesion (p = 0.38).
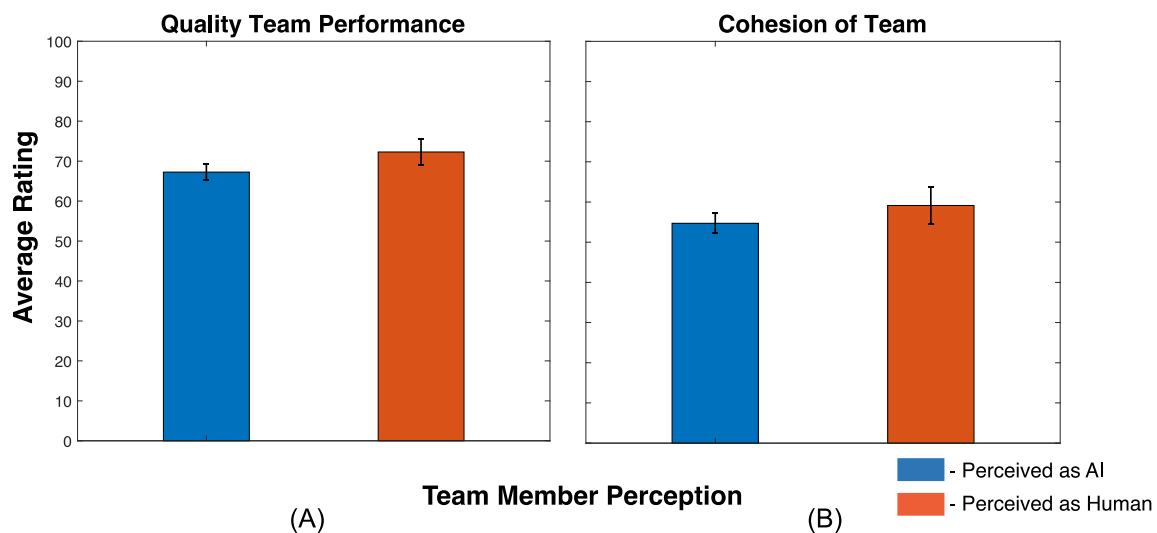

Figure 2. Average rating from team members on the (A) quality of performance of their team and (B) the cohesion of their team. Error bars show ±1 standard error.

However, differences start to emerge when asking whether teams follow the interventions from the process managers (Figure 3) and about different characteristics of the interventions (Figure 4A, 4B, and 4C). On a categorical scale from "Always" to "Never", Figure 3 shows that when team members perceive the process manager as a human, they trend towards being more likely to follow the interventions than if they perceive the process manager as an AI agent. Similarly, Figure 4 shows that if team members perceive the process manager as human, members discern the interventions as marginally more relevant (p = 0.073), significantly more helpful (p = 0.01), and the process manager as significantly more sensitive to the needs of the team (p = 0.018). These results show that there exists a bias for human process managers as being overall more helpful, compared to when the process manager to is believed to be an AI agent. These results are interesting because when comparing the same questions by the actual team conditions (human-managed teams versus AI-managed teams), no differences emerged (Gyory et al., 2022) showing that the belief that the management was human rather than the reality is what mattered. The results in the next section provide explanations why these differences exist and set a course for further development of the AI agent and automated process management.

3.2. Development of Future AI Process Managers

As the previous results show, a bias exists for when team members perceive the process manager to be a human versus an AI agent. Supplemental questions within the post-study questionnaire begin to uncover distinctions between the two types of process managers and ways that the agent can be improved for future development. First, as Figure 1 indicates, 75% of all participants believe the manager to be an AI agent, even when all members were evenly distributed across both process manager conditions. Question seven from *Section 2.3* asks participants what characteristics of the manager made
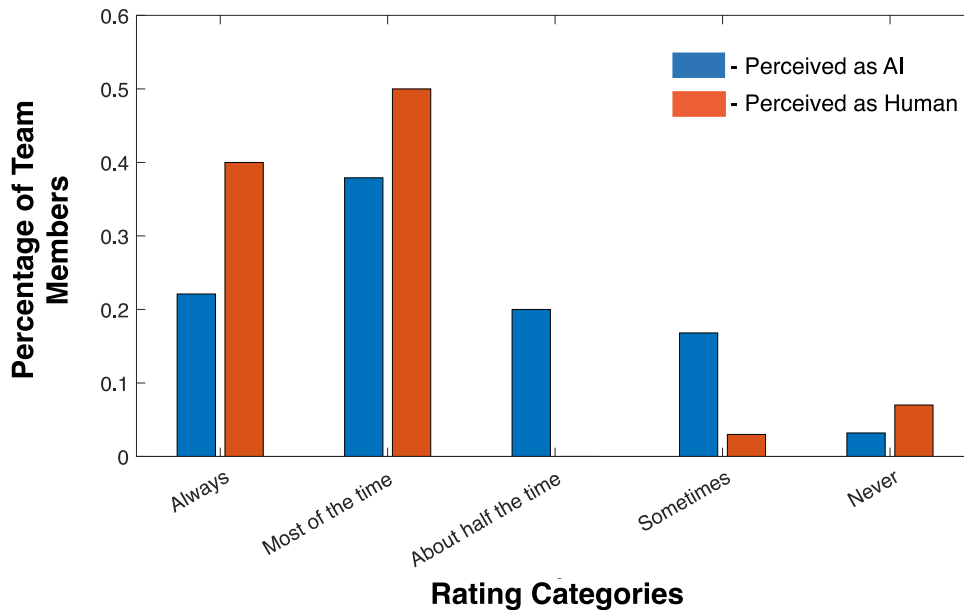
Figure 3. Proportion of team members rating how often they followed the interventions provided by the process managers.
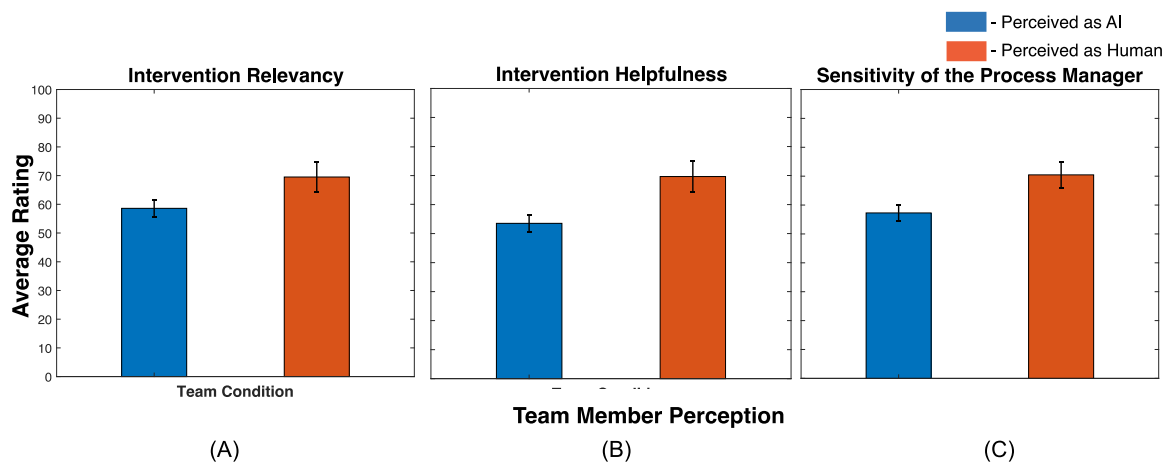

Figure 4. Average rating from team members on the (A) relevancy of the interventions, (B) helpfulness of the interventions, and (C) sensitivity of the process manager to their teams' needs. Error bars show ± 1 standard error.

them discern the manager in the way that they did. Several main themes that emerge include using repetitive language (when a team receives the same intervention multiple times throughout the experiment), having the intervention language sound overtly formal/scripted, having the interventions be too general/vague, and not providing feedback. For example, participants report that, "*it* [the process manager] *didn't seem personalized and was repetitive*," and "*communications from the system seemed pre-set and not delivered in the style that a human would.*" However, these results are not too surprising, as some of these design choices are deliberately made to mitigate some of the extra variability within the experimental design. For example, the authors decided to go with a prescribed set of interventions, with the same language, as opposed to process managers improvising interventions in real time. In this way, we could ensure that the differences in language did not become an extraneous variable when analysing intervention impacts.

The next question (question eight) explores different team process measures to track by querying the human process managers for reasons causing them to or to not intervene with their team. Some

common motivations emerge across both. For reasons to intervene, managers express that a lack of communication or a lack of effective communication prompt them. Furthermore, when designers seem stuck, via a slow pace of actions, the managers feel it necessary to mediate. On the other hand, managers express it unnecessary to intervene during sufficient or effective information ("There was lots of good communication between all the members. There was success in their endeavors that I could see through the chat window"). The reason they provided includes not wanting to disrupt the flow of information sharing, such as when drone designs/operations plans are being submitted and requirements are being met or when the problem manager is effective in their role. The latter reason agrees with the particular team structure in the experiment, as the problem manager bridges the communication between the drone designers and operations specialists. One participant sums up sentiments from most managers, saying "The main reason I chose to intervene with my team was when there was a long period of time without communication or if it appeared that they were not working together as well as they should. I chose not to intervene when there was consistent communication and designs were being submitted/worked upon." These results are useful as they provide some critical features to observe in real-time tracking.

The two final items, both in the process managers' and the interacting team members' questionnaires, ask what types of additional interventions they would have liked to provide/receive during problem solving. First, it is important to note that nearly all but one of the process managers feel constrained using the prescribed intervention set provided to them. Expressing other desired types of interventions, participants discuss benefiting from more individualized (to specific team members as opposed to the entire discipline as is currently done in accordance with Table 1) and customized (i.e., speak directly to the team) interventions, those focused on specific goals and feedback, and positive reinforcement. The latter idea is interesting as a few of the process managers (and even a few team members) suggest in lieu of the "No Intervention" option, they would appreciate a way to express positive reinforcement to help the morale of the team or to promote effective behaviours. Overall, the first three rationales can be attributed to the experimental design choices and overarching goal of the experiment. For example, the interventions do not relate to the specific goals of the task because the research focuses on process management of the design teams. Regardless, these questions within the post-study questionnaire provide insight into further implementations of automated process management, as discussed in the next section.

4. Discussion & Future Work

This research explores the perceived impacts of process management on engineering design teams based on how team members discern the identity of said manager. As literature has shown, this perception of 'humanness' of AI assistance can pose downstream effects on both individuals reliance and performance. While participants are not specifically deceived on the process manager's identity, it is also not revealed to them that the manager could be a human or an AI agent, or that this could even be the goal of the experiment. Queries within the post-study questionnaire enable the research to address how this perception may affect their compliance with and assumptions about the impact of the interventions on their performance and process. Questions within these surveys also help in directing expansions of automated process management and AI trust for future research.

Overall, participants mainly discern the process manager as an AI agent. Regardless of a near even split of experimental conditions, 75% of all participants believe this. However, their rationale can be explained via a post-study survey, and a large part can be attributed to the choices made within the experimental design. Members characterize the scripted, formal, and repetitive nature of the language to be robotic and therefore attributed to an AI agent. However, this knowledge can be leveraged to guide further iterations of the process manager. For example, instead of providing the same intervention multiple times in a row, the process managers can supply a different iteration to semantically convey the same intention. In fact, this exact suggestion emerges from participants: "They resent the same suggestion three times in a row, I feel a human would try to rephrase it in a better way if it didn't get through to use the first time." While the researchers piloted different variations of interventions, a greater emphasis for the future can be placed on improving the language to become more colloquial. Some team members note that the process manager "seemed kind of blunt

and lacked personality or detail," and made "very anti-personal statements," by "addressing us with 'Team.'" But why does this matter? Well, the results of this study also show that participants have a bias for human managers. Even though the human managers provide the same distribution of intervention types, access the same team behaviours, and induce similar levels of team performance, team members still perceive them differently. The results show that when members believe a human guides them, they discern interventions as significantly more helpful, their team as significantly more cohesive, and the manager as significantly more sensitive to the needs of the team. These perceptions on cohesiveness and other team characteristics can have further downstream effects on team interactions such as team morale and effort (Paul et al., 2016). This could explain why the subset of team members who thought they were human-managed, and were, felt this way even though they performed marginally worse over time. While this work focused on student designers, further examinations can identify whether similar perceptions between human and AI process managers extend to expert designers in practice.

In addition to the formal language of the process managers, participants' notes on direct, goal-specific interventions and feedback may be attributed to the original objective of the study. The research objective includes studying the impact of process management on design teams. In this way, the interventions are designed to focus specifically on process, rather than the artifacts being designed/worked on. This is the fundamental reason why the interventions relate to global communication/action behaviours and communication semantics. Nonetheless, these are interesting opinions from the team members and certainly present opportunities for studying product management. In this type of scenario, an agent could track how the design evolves over time within the design space of possible solutions, how the designs match up to specific constraints and specifications, and how much their designs need to change to match these criteria. Interventions can be developed to push designers' products in certain directions. As this is not the goal of process management, this is left for future work. Along the same vein, another interesting avenue of work can study the combinations and varying levels of process-based and product-based management, extracting different managerial strategies and their impacts on problem-solving behaviours and effectiveness.

5. Conclusion

As human-AI assistance and hybrid teaming becomes a part of a wider array of applications and interests, research on human-AI trust and effectiveness become more critical. With the specific application of managing the process of human design teams, this research studies human perceptions of an AI process manager agent. Broadly, this study shows that there exists a bias for human process managers, who are perceived as more sensitive to the needs of the team, and provide more relevant interventions, even though participants are blind to the identity of this process manager. Moreover, this study delivers insights into further development of automated process management, such as the importance of more colloquial intervention language, goal-directed feedback, and positive reinforcement. While not directly queried in this work, the underlying themes throughout indicate that humans may still not be fully trusting of AI agents in a managerial role. Perhaps an agent with the ability to provide specific and direct feedback in a less formal manner may shift these perceptions. This work certainly sets the stage for these further studies in automated process management.

Acknowledgement

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