Early Chatbot Assistance Can Enhance Team Decision-Making by Promoting Cognitive Diversity and Information Elaboration

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Abstract

As AI increasingly assists teams in decision-making, the study examines how technology shapes team processes and performance. We conducted an online experiment of team decision-making assisted by chatbots and analyzed team interaction processes with computational methods. We found that teams assisted by a chatbot offering information in the first half of their decision-making process performed better than those assisted by the chatbot in the second half. The effect was explained by the variation in teams' information-sharing process between the two chatbot conditions. When assisted by the chatbot in the first half of the decision-making task, teams showed higher levels of cognitive diversity (i.e., the difference in the information they shared) and information elaboration (i.e., exchange and integration of information). The findings demonstrate that if introduced early, AI can support team decision-making by acting as a catalyst to promote team information sharing.

Keywords

Artificial intelligence, chatbot, team cognition, decision-making, temporal dynamics

Introduction

Artificial intelligence (AI), such as chatbots and virtual assistants, has the potential to enhance human cognition and team decision-making due to its advanced cognitive abilities. Although recent work has started to examine how individuals may utilize the advice from AI (Logg et al., 2019), investigation on AI and team decision-making remains scarce despite the increasing application of AI in organizational teams (Sebo et al., 2020; Yan and Gurkan, 2023). As one of the major tasks performed by teams (McGrath, 1984), collective decision-making entails sharing, analyzing, and integrating information distributed among team members because members often possess different expertise and hold unique information regarding the decision at hand (Mell et al., 2014; Van Ginkel and Van Knippenberg, 2008). However, one of the major paradigms in team research has established that, in fact, teams are often not good at exchanging different information and prefer to discuss shared information, which leads to premature consensus and bad decisions (Lu et al., 2012).

The current study investigates how AI assistance may improve team decision-making. In particular, we are interested in how AI assistance introduced at various team stages may influence team information-sharing processes and, consequently, the quality of team decisions. We focus on two team information-sharing processes in decision-making – cognitive diversity and information elaboration. Cognitive diversity refers to the variety in information, information processing styles, and perspectives (Sauer et al., 2006). Information elaboration is the process in which team members exchange, discuss, analyze, and integrate their information (Mell et al., 2014; Van Ginkel and Van Knippenberg, 2008).

Cognitive diversity and information elaboration are critical processes that lead to high-quality team decisions (Mell et al., 2014; Sauer et al., 2006). Cognitive diversity stimulates constructive discussion in teams as it encourages teams to challenge the suggestions of others, justify their own positions in the face of opposition, and discuss opposing perspectives toward a solution (Simons et al., 1999). Thus, when cognitive diversity is high, information elaboration is likely enhanced. When teams have higher cognitive diversity, if a team member takes the initiative to share unique information, other members who are hesitant to share their own lack of knowledge may be encouraged to ask for information as well (Van Ginkel and Van Knippenberg, 2008). As a result of these information-sharing processes, teams will make better decisions. Since AI can perform tasks such as collecting, analyzing, and providing information, it may impact team decision-making by altering team members' information-sharing processes. Thus, the current study asks:

RQ1 How does introducing AI assistance at different team stages impact team decision-making performance?

RQ2 To what extent can AI assistance impact team decision-making performance by affecting team a) cognitive diversity and b) information elaboration?

Methods

To answer our research questions, we carried out an online experiment in which groups of four participants worked on a decision-making task via video chat on the video conferencing platform Zoom. The task involved a hidden-profile scenario where crucial information was dispersed among team members (Mell et al., 2014). In the task, participants acted as a team of consultants and advised their client on the best new product to develop for the next season from five options. Information needed to make the decision was distributed among team members. Participants had 10 minutes to read their information packet and 15 minutes to discuss before they offered a rank order of the five products.

The experiment followed a 2 × 2 between-subject factorial design (N = 47). The first factor, Chatbot Assistance (first-half vs. second-half), manipulated the timing of chatbot assistance. Teams either received chatbot assistance in the first half of the team decision-making task or the second half. In both conditions, the chatbot sent out three identical messages containing information needed for the decision at two-minute intervals. The chatbot was shown as a participant in the Zoom conference with a profile picture but no video or audio. It interacted with the participants via chat messages. The setup of the chatbot mimics how Zoom chatbots are incorporated into the platform (Chaves and Gerosa, 2021). Following a common approach in human-AI interaction research (Sebo et al., 2020), we manipulated the chatbot using the Wizard-of-Oz method to ensure consistency. The second factor, Information Distribution (fully vs. partially distributed), varied the distribution of task information among team members. In all conditions, all members had to share their unique information to make the best decision.

The study recruited 220 participants from two sources - an online platform, Prolific, and a group of undergraduate psychology students from a private university in the US. Participants were randomly assigned into groups of four. They were required to keep their audio and camera on during the team task, so the team interaction processes were recorded. Forty participants in 10 teams were excluded from the analysis due to missing members because of unstable internet connections. The final sample consisted of 45 teams and 180 participants. Among them, 97 were male, 82 were female, and one was non-binary. The age of participants ranged from 19 to 57, with a mean of 24.3. There were 9 Asian, 99 African American or Black, 45 White, and 27 other categories. English was the primary language for all participants.

Measures

Dependent Variable: Team Performance

The quality of team decisions was measured by their performance score, based on how similar their rankings were to the objectively correct ranking. Mell et al. (2014) explained that the team performance score was determined by calculating the deviation of a team's rank from the optimal rank position for each of the five product innovations. The sum of these five deviation scores gave an overall score ranging from 0 to 12. To make the score easier to understand, the value was subtracted from 12, with higher scores indicating better performance.

Cognitive Diversity

We applied a computational model to measure cognitive diversity in teams. Whereas previous studies have relied on self-reported measures to assess shared cognition in groups, Lix et al. (2022) suggested that analyzing the language used by team members when communicating with each other could provide more detailed and objective measures of cognitive diversity within the group.

We created a language-based tool to gauge cognitive diversity by utilizing sentence embedding models belonging to a family of unsupervised machine-learning techniques representing sentences in a high-dimensional vector space. We selected the publicly available Universal Sentence Encoder (USE) (Cer et al., 2018) on TensorFlow Hub for its ability to achieve consistently good performance across multiple NLP tasks. The model was trained on the Stanford Natural Language Interface (SNLI) corpus, Wikipedia, web question-answer pages, web news, and discussion forums. It outputs a 512-dimensional vector of text. The dimensions of an embedding space correspond to hidden features that underlie language use in the text. Sentences with similar meanings are positioned closer together in the space.

We transcribed the audio-video recordings of team interaction into text using Amazon Transcribe. We manually corrected the inaccurately transcribed sentences and partitioned each team member's speech. We concatenated each team member's text across the entire team discussion as well as for the first half and second half. The concatenated text was used as input to USE to obtain each team member's text vector representation. We used normalized text vectors, in which the magnitude of the vectors was scaled to be equal to 1.

We calculated the cognitive diversity metric for every team for the entire team discussion and within the first and second half of the discussion. Let *I* be a team of *N* individuals, and W_{it} denote the concatenated spoken text expressed by the individual, *i,* during a time period, *t*, as derived from the individual's use of language during that time. We define the embedding distance between two individuals, *i* and *j*, during time *t*, as the cosine distance between their respective embedding:

$$d(W_{it}, W_{jt}) = 1 - cos(\overline{W}_{it}, \overline{W}_{jt}),$$

where cos(A, B) = $\frac{AB}{\|A\|\|B\|}$. Using this distance metric, we define a team's overall cognitive diversity as the average pairwise embedding distance between all team members.

$$CD_{It} = \frac{\sum_i^N \sum_j^N d(W_{it}, W_{jt})}{N^2}.$$

Information Elaboration

Information elaboration was measured based on the rating scheme used by Mell and colleagues (2014). The rating scheme assigned a score from 0 to 5 to each information item discussed. To receive a score higher than 0, the item must have been mentioned during the discussion. A score of 1 was given when a team member mentioned an item, and a 2 WAS given when the item was acknowledged by at least one other team member or mentioned in response to a question but was not further discussed. A score of 3 was awarded when a team member asked a clarifying question about the mentioned item. A 4 was given when a conclusion was drawn from the item without explicitly integrating it with other information. And a 5 was given when the item was combined with another piece of information. Two raters unaware of the experimental conditions independently rated the transcripts of team discussions. The two raters assessed 10 overlapping teams. The inter-rater reliability of the coding scheme was determined using intraclass correlations (ICCs) and was high (> 0.85).

Results

A 2 x 2 ANOVA was conducted to analyze the effects of chatbot assistance timing and information distribution on team performance. In response to RQ1, the analysis revealed a significant main effect of chatbot assistance timing on team performance, F(1, 41) = 4.99, *p* = .03. Teams supported by the chatbot during the first half of the discussion performed significantly better (*M* = 8.16, *SD* = 2.57) than those assisted by the chatbot during the second half of the discussion (*M* = 6.57, *SD* = 2.47). Information distribution did not have a statistically significant effect on team performance, F(1, 41) = 2.26, *p* = 0.13.

Cognitive Diversity

A 2 × 2 ANOVA was performed to compare the level of cognitive diversity in the four experimental conditions. The analysis revealed a significant main effect of chatbot assistance timing on the team's overall cognitive diversity, *F*(1, 41) = 7.42, *p* = 0. The teams assisted by the chatbot in the first half of the discussion had higher overall cognitive diversity (*M* = 0.53, *SD* = 0.13) than those assisted by the chatbot in the second half (M = 0.43, SD = 0.09). Information distribution did not significantly affect the team cognitive diversity score, $F(1, 41) = 0.93$, $p = 0.33$. These results suggest that teams assisted by the chatbot in the first half shared more diverse information in the team interaction than teams assisted by the chatbot in the second half.

To further explore how the chatbot influenced team cognitive diversity, we analyzed the effect of chatbot assistance and information distribution on cognitive diversity in the two halves of the discussion. A 2x2 ANOVA analysis revealed a significant main effect of chatbot assistance timing on team cognitive diversity in the first half ($F(1, 41) = 9.52$, $p < .01$). Teams assisted by the chatbot in the first half of the discussion had higher cognitive diversity (M = .41, SD = .09) than teams assisted in the second half of the discussion (M = .30, SD = .12). Information distribution and the interaction between the two experimental conditions had no significant effect on first-half cognitive diversity in teams ($F(1, 41) = .02$, p =.87; $F(1, 41) = .34$, $p = .55$). A 2x2 ANOVA analysis also showed no significant effect of chatbot assistance, information distribution, or their interaction on team cognitive diversity in the second half of the team discussion. Taken together, increased team cognitive diversity might be a driving factor for the effect of chatbot assistance timing. Introducing chatbot assistance in the early stage of team decision- making significantly promoted cognitive diversity in teams at the beginning of the team discussion. However, having chatbot assistance in the later stage of team decision-making did not seem to be as effective.

Information Elaboration

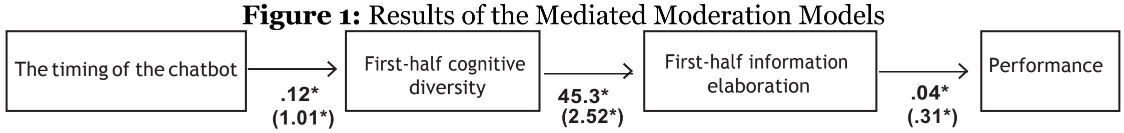
A two-way ANOVA was performed to analyze the effect of experimental conditions on information elaboration. We found a significant main effect of chatbot assistance ($F(1, 41) = 4.59$, $p < .05$) and information distribution on information elaboration ($F(1, 41) = 3.75$, $p < .05$). Teams assisted by the chatbot in the first half elaborated more information (M = 59.2, SD =14.2) than teams assisted by the chatbot in the second half (M = 47.7, SD = 19.9). Teams with fully distributed information elaborated more information (M = 59, SD =17.1) than teams with partially distributed information (M = 47, SD =17). The interaction between the two experimental conditions was not significant (F(1, 41) = .19, $p < .66$).

We also examined the information elaboration in two halves of the team discussion separately. A two-way ANOVA analysis demonstrated a significant main effect of chatbot assistance on information elaboration in the first half ($F(1, 41) = 13.5$, $p < .001$) and no effect on information elaboration in the second half ($F(1, 41) = 0$, $p = .93$). Information distribution did not significantly affect information elaboration in either half of the team discussion ($F(1, 41) = 1.2$, $p = .27$; F(1, 41) = 3.97, $p = .06$). There were no significant interaction effects of the two conditions ($F(1, 41) = .63$, $p = .47$; $F(1, 41) = 2.05$, $p = .15$). In summary, the results suggest that the positive effect of having chatbot assistance on information elaboration in the first half of team decision-making was primarily due to the increase in the early stages of team discussion.

The Mediating Roles of Cognitive Diversity and Information Elaboration

RQ2 asked to what extent the main effect of chatbot assistance on team decision-making performance is mediated by cognitive diversity and information elaboration in team discussion. To answer this question, we conducted multiple serial mediation analyses suggested by Hayes (2013). We used cognitive diversity and information elaboration in the first half of the team discussion as the mediators since our previous analysis suggests that chatbot assistance made the most significant difference in these two variables. The results of the analysis are graphically illustrated in Figure 1.

Figure 1: Results of the Mediated Moderation Models



Note: Path estimates are unstandardized regression coefficients, standardized regression coefficients are in parentheses. * $p < .05$

In the initial steps of the analysis, regressing team performance on the experimental conditions and their interaction reproduces the main effect of chatbot assistance timing discussed earlier. Regressing teams' cognitive diversity in the first half of the discussion on the experimental conditions and their interaction yielded the path coefficients for the first stage of the mediation model. The results showed a significant effect of chatbot timing on team cognitive diversity in the early stages of team discussion (β = .12, $p < .05$). Next, regressing information elaboration in the first half of the discussion on the conditions, their interaction, and the team's cognitive diversity in the first half of the discussion yielded the path coefficients for the second stage of the mediation model. The team's cognitive diversity in the first half of the discussion significantly predicted information elaboration in the first half of the discussion (β = 45.3, $p < .05$). Finally, regressing team performance on the complete series of predictors yielded the path coefficients for the last stage of the mediation model. In this model, information elaboration in the first half of the team discussion (β = .04, $p < .05$) and information distribution (β = 2.1, $p < .05$) significantly predicted team performance, while neither the chatbot timing nor cognitive diversity in the first half of the discussion showed any significant effect. To conclude, the analysis revealed that the impact of chatbot assistance timing on team decision-making was mediated by cognitive diversity and subsequently by information elaboration.

Discussion and Conclusion

Our study explores how the use of AI can enhance team decision-making performance by influencing team information-sharing processes. In particular, we focus on how the introduction of AI at different stages of team collaboration affects the team's cognitive diversity and information elaboration and, subsequently, the overall quality of their decisions. The results of an online experiment indicated that teams who received assistance from a chatbot during the early stages of their collaboration performed better than teams who received chatbot assistance at a later stage. The difference in decision quality between the two chatbot conditions can be explained by the variation in how the teams share information. Teams that received chatbot assistance during the initial stages of the decision-making task demonstrated higher levels of information elaboration and cognitive diversity, thus promoting information-sharing quality and decision-making outcomes. Overall, our findings suggest that receiving AI assistance at the beginning of team decision-making can be socially and cognitively beneficial for teams because it can enhance team information exchange.

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