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"An Ideal Human": Expectations of AI Teammates in Human-AI Teaming

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Driven by state-of-the-art AI technologies, human-AI collaboration has become an important area in computer-supported teamwork research. While human-AI collaboration has been investigated in various domains, more research is needed to explore human perceptions and expectations of AI teammates in human-AI teaming. To achieve an in-depth understanding of how people perceive AI teammates and what they expect from AI teammates in human-AI teaming, we conducted a survey with 213 participants and a follow-up interview with 20 participants. Considering the context-dependency of teamwork, we chose to study human-AI teaming in the context of multiplayer online games as a case study. This study shows that people have mixed feelings toward AI teammates but hold a positive attitude toward future collaboration with AI teammates in general. Our findings highlight people's expectations for AI teammates in a rapidly changing collaborative environment (e.g., instrumental skills for in-game tasks, shared understanding between humans and AI, communication capabilities, human-like behaviors and performance), as well as factors that impact people's willingness to team up with AI teammates (e.g., pre-existing attitudes toward AI, previous collaboration experience with humans). We contribute to CSCW by shedding light on how AI should be structured in human-AI teaming to support highly complex collaborative activities in CSCW environments.

CCS Concepts: • **Human-centered computing** → **Collaborative and social computing**.

Additional Key Words and Phrases: human-AI teaming; human-AI collaboration; multiplayer online games; teamwork; AI design

ACM Reference Format:

Rui Zhang, Nathan J. McNeese, Guo Freeman, and Geoff Musick. 2020. "An Ideal Human": Expectations of AI Teammates in Human-AI Teaming. *Proc. ACM Hum.-Comput. Interact.* 4, CSCW3, Article 246 (December 2020), 25 pages. <https://doi.org/10.1145/3432945>

1 INTRODUCTION

With rapid advancements in machine learning algorithms, artificial intelligence (AI) is increasingly equipped to collaborate with humans on various tasks from massive data processing [60] to decision-making [21]. In the past decade, advanced AI techniques have led to an emerging research agenda on human-AI collaboration in the CSCW/HCI community, exploring important topics such as children's education [63], medical practice [50], and artwork co-creation [37]. A great deal of CSCW work on human-AI collaboration focuses on various team-level activities, such as

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2573-0142/2020/12-ART246 \$15.00

<https://doi.org/10.1145/3432945>

coordination between humans and AIs through implicit communication [38, 47] and collaborative decision-making [7]. These team-level activities play an important role in shaping team outcomes in human-AI teams in CSCW.

Such progress in human-AI collaboration has led to increased growth and interest in human-AI teaming, where humans and intelligent agents coordinate with each other and perform high-complexity tasks as an integrated unit. As a subset of human-AI collaboration, *human-AI teaming* emphasizes very close coordination between humans and AI teammates with a shared goal. Specifically, humans and AI teammates are required to share essential information via various types of communications, predict teammates' actions, and progress through tasks utilizing high-level coordination. CSCW researchers focused on human-AI teaming have explored people's bias (unfairness) toward AI teammates in blame assignment due to game failure [45] and protection behaviors in collaborative games [48]. In addition, previous CSCW research also investigated the impact of various factors on team performance (e.g., implicit communication, human's mental model of AI's error boundary) in human-AI teaming [3, 38].

This body of work has shed light on an initial understanding of human-AI teaming by focusing on human behaviors and team performance. However, two research gaps still emerge in existing studies in the field of human-AI teaming. First, little research on human-AI teaming focuses on people's perceptions of *AI teammates* in CSCW. Despite some work in the field of human-AI collaboration focusing on understanding how AI tools are perceived by humans [21, 53], little work has studied people's perceptions of *AI teammates* in human-AI teaming. In contrast to using AI as a tool, treating AI as a real teammate means that people put higher expectations on AI agents and expect them to perform in certain ways. Understanding how AIs are perceived as teammates in highly collaborative scenarios provides insight regarding how best to organize human-AI teams to enrich human-centered interactions.

Second, little attention in human-AI collaboration research has been placed on humans' *expectations* of AI teammates in complex tasks. In light of this, it is essential to understand what people expect from AI teammates in human-AI teaming, which paves the way for a human-AI unit where humans and AI share vital information, anticipate teammates' behaviors, and coordinate at a high level to produce high team performance. Additionally, human expectations of AI teammates will promote algorithmic advancements in regard to how AIs are expected to understand teamwork and behave. These advances should take into consideration how humans seek to interact and collaborate with AIs at a high level of collaboration for the purpose of teaming.

In this paper, we seek to address these gaps by exploring people's perceptions and expectations in human-AI teaming. Using a survey study (N=213) and a follow-up interview study (N=20), we focus on the following research questions:

RQ 1.1: How do people perceive current AI teammates?

RQ 1.2: What factors are related to people's willingness to team up with AI teammates?

RQ 2: What do people expect from AI teammates in human-AI teaming?

Given the complexity of human-AI collaboration under various scenarios, as well as divergent needs of human-AI teaming in different domains [20, 24], it is essential to explore human-AI teaming in a concrete domain to achieve an in-depth understanding. Investigating human-AI teaming without a specific context increases the complexity of understanding how people perceive AIs in a collaborative environment and may lead to a general and superficial comprehension of human-AI teaming. Therefore, in order to achieve an in-depth comprehension of people's expectations in human-AI teaming, we used multiplayer online gaming as a specific context to explore our research questions. Our choice was based on four reasons. First, the multiplayer game environment consists of dynamic flow and complex collaborations. Various types of collaboration

are involved in team-based gameplay, such as decision-making and explicit/implicit coordination [9, 17, 64], which make it a broader context for human-AI teaming. Second, researchers are able to observe participants' behaviors and collect rich data in the context of multiplayer online games, which provides researchers an opportunity to achieve in-depth comprehension of collaboration with AI. Third, compared to many other domains (e.g., healthcare, autonomous industry, finance), online games are more accessible to individuals. Moreover, the online environment of games enables people to interact with AI directly, which indicates people have an understanding of the context and can describe more specific expectations of AI teammates. Finally, multiplayer online games are well-suited for investigating our research questions since it is more feasible to design, develop, and implement AIs in online games. In sum, multiplayer online gaming is a unique research context in terms of its special features (e.g., various types of collaboration and coordination; dynamic flow) and accessibility.

This study makes a number of contributions to CSCW and HCI. First, we extend existing CSCW research on human-AI teaming by shedding light on people's perceptions of AI teammates. This perspective could be applied to structure human-AI teams to optimize team performance. We also examine factors that influence people's willingness to team up with AIs in human-AI teaming. Second, we contribute to the understanding of people's expectations of AI teammates in human-AI teaming. This understanding will further assist CSCW researchers in better structuring human-AI teams in high-complexity, collaborative environments. Additionally, we provide design implications for future human-AI teams in terms of how AI teammates and the collaboration between humans and AI teammates should be structured.

2 BACKGROUND

In this section, we review existing CSCW and HCI studies on (1) perceptions of AIs, which is crucial in understanding how to design human-AI teams to promote team outcomes, (2) human-AI teaming, the core concept of this study, as well as (3) teamwork in multiplayer games, used as our research context to explore complex collaborations.

2.1 Perception of AI

Previous research has highlighted multiple themes regarding how humans perceive individual AI, including: AI's reliability, explainability of AI algorithms, and biases toward AI. With perceived reliability and explainability playing an influential role in the generation of trust of AI [13], it is also important to understand how human biases toward AI can hinder trust [39, 55]. Importantly, since many of these studies investigated how humans perceive individual AI, additional work is needed to explore human perceptions of AI in collaborative *team* environments [34, 53].

Perceived reliability of AI plays an influential role in how much humans trust and utilize AI. For example, Kerr et al. found that providing AI's data transformation process to healthcare workers increased their perceived reliability of the data quality [31]. Hayashi et al. examined the impact of the perceived reliability of AI during the decision-making process in a court scene [21]. In this study, it was demonstrated that AI was perceived the same as a human from the reliability aspect. Previous studies have also shown a higher perceived reliability toward AI than humans in decision-making. Madhavan et al. explored operators' perception of AI aids in decision support systems and concluded that AI was perceived as more reliable than humans during the decision support process [42]. This conclusion was also presented earlier in another study that analyzed the perceived utility of human aid compared to AI aid [15].

Due to AI's black-box feature (i.e., a system that only shows input and outputs without showing the decision process), a desire for explainability has arisen [39, 55]. Specifically, attention has focused on Intelligible AI and Explainable AI (XAI), generally centering on designing transparent

and interpretable AI algorithms [11, 20, 39]. Prior work indicates evidence that AI with intelligible, accountable, and explainable features are more likely to build trust with humans [62]. In particular, the development of XAI allows AI algorithms underneath the interface to be more comprehensible and more transparent to improve people's understanding of AI [39]. However, existing work centers more on the technical perspective of AI than on human-centered aspects [1, 16]. For example, evolutionary fuzzy systems were proposed for XAI to better balance accuracy with explainability of AIs [16]. Samek et al. explored the explaining of deep learning models [57]. Kumar et al. proposed a new approach, CClass-Enhanced Attentive Response (CLEAR), to visualize and explain decision-making processes of deep neural networks (DNN) [35].

Though AI is sometimes perceived as more or of similar reliability as humans for specific tasks (e.g., massive data processing, data mining, decision-making) in which AI's algorithm attributes are utilized [21], some other studies present how humans form a negative bias towards AI [53, 55] due to its machine nature. For example, Ragot et al. explored bias toward AIs in computational creativity through a large-scale experiment and showed that a negative bias toward AI exists in creative activities/works [53]. Rossi highlighted possible bias toward AI during decision-making processes due to AI's black-box feature [55].

Although a body of CSCW literature has investigated various types of perceptions of individual AI and how these perceptions influence collaboration between humans and AI, understanding people's perceptions of human-AI teaming within CSCW environments is beneficial to better structure human-AI teams to achieve high team performance. Thus, we argue that more work is still needed to further explore human-AI teaming for two reasons. First, how people perceive an AI teammate is different from how they perceive an individual AI since teamwork requires close coordination between teammates. Second, understanding how people perceive human-AI teaming and how people expect AI teammates to behave in human-AI teams is essential to build and maintain a high-performance human-AI team. These insights will inform the further design of human-AI teams for more effective and genuine collaboration between humans and AI teammates.

2.2 Human-AI Teaming in CSCW

Currently, we are approaching a *human-computer symbiosis* stage, in which humans and AI closely collaborate with each other in an equal partnership [19]. Based on the definition of human-human teams, *human-AI teams* are defined as a mixed entity of two or more subjects (i.e., at least one each being human or AI), who interact interdependently and perform shared tasks to achieve the same valued goals [10, 44, 56]. Compared to human-human teaming, human-AI teaming is still at an early stage of development and implementation and has become an important research area in CSCW and HCI [28, 38, 47, 59, 60].

One such example of human-AI teaming research pertains to team performance. Previous work has shown that while high-performance AI enhances people's trust [65], accuracy is not a direct factor to predict team performance [3]. Rather, improving accuracy of AI systems without considering compatibility with previous versions of the system and user experience may hurt the trust built between humans and AI [4]. Therefore, to further investigate the team performance of human-AI teams, more attention should be paid to team-level performance and interaction rather than limited to individual performance and ability.

Similar to human-human teamwork, the establishment of shared mental models plays a crucial role in high-complexity human-AI collaborative teamwork. Previous work has studied the enhancement of the shared mental models in a mixed human-AI team. For example, Hong et al. proposed a conceptual model for collaborating agents to improve shared situation awareness between humans and agents in collaborative sensemaking [23]. Kaur et al. proposed approaches for building shared mental models between humans and AI that enable them to collaborate at a team level rather than

simple human-AI interactions [29]. In this way, humans and AIs could anticipate the distribution of tasks, as well as teammates' behaviors in specific scenarios, leading to more efficient collaboration and higher team performance.

Another core component in teamwork is communication that facilitates team coordination through decision-making and task allocation. Communication is a significant challenge to human-AI teamwork. A large amount of effort has been devoted to natural language processing in an attempt to improve human-AI communication [6, 43]. In addition to explicit communication via natural language processing, implicit communication is another direction of human-AI communication research. Liang et al. found that implicit communication in human-AI teams has a positive influence regarding how human players perceive collaboration with AI using a collaborative board game [38]. This study also showed that implicit communication should be considered as a factor in creating an effective AI teammate [38].

Others have also explored the differences between human-human teams and human-AI teams. Jung et al. explored the effect of a robot intervention on people's perception of conflicts in a team-based task and found that it increased the conflict awareness within the team [27]. Humans are more likely to blame their real/presumed AI (presumed AI refers to humans who pretend to be an AI) teammates for the failure compared to real/perceived human teammates in cooperative online games [45]. Another study also indicated that humans are more likely to save a presumed human teammate (AI teammates who pretend to be a human) than real AI teammates in a cooperative game [48]. In addition, this study found that people were less likely to assess their teammate's skills accurately in human-AI teams in contrast to human-human teams [48].

In line with these studies, we argue that it is crucial to understand human-AI teaming from a human-centered perspective. Despite advanced machine learning algorithms, human-AI collaboration is still a challenging topic given the limitations of AI (e.g., lack of creative thoughts, inadequate team awareness, limited natural language communication). First, human-AI teaming requires AIs to develop collaboration awareness. Second, humans must adapt to the new type of collaboration as well as be equipped with an understanding of their AI teammates. Therefore, in this study, we hope to understand how people perceive collaboration with AI teammates (i.e., what they expect from AI teammates) and what motivates people to develop such expectations. In the next section, we will review studies of teamwork in multiplayer online games, our research context.

2.3 Teamwork in Multiplayer Online Games

Multiplayer online games are designed in a manner to encourage players to communicate, interact, and collaborate with other players (both human and AI) aimed at accomplishing team-level goals [5, 14, 58]. Considering the complex collaborative environment offered by multiplayer online games, teamwork does not only need the contribution of individual skills, but also the implementation of team-level skills (e.g., problem solving, communication, coordination, decision-making) to achieve high team performance. A great deal of work has explored teamwork skills in collaborative game environments [58, 61]. For example, Sourmelis et al. proposed a KSAVE (Knowledge, Skills, Attitudes, Values, Ethics) framework based on previous empirical research in multiplayer online games to describe various teamwork skills (e.g., critical thinking, problem solving, and decision-making) [58].

In addition to teamwork skills, each team member's role within the structure of the team is also crucial to successful team performance. Pobiedina et al. examined the impact of game roles, previous game experience, friendship among team members, as well as leadership on game outcomes and concluded that teams with a better pattern (role distribution in the game as well as in the team) are more likely to achieve team success [52]. Wang et al. examined five roles in a teamwork structure

with corresponding teamwork skills and found that various roles facilitated the improvement of different teamwork skills [61].

Compared to teamwork in offline environments, communication is considered a more challenging issue in shaping virtual team outcomes due to lack of nonverbal cues caused by spacial separation [32]. Given the fast-paced and competitive features of multiplayer online games, teams that collaborate in such complex environments still have difficulty completing collaborative activities (e.g., decision-making, team coordination) collectively via precise online communication. Tacit communication has been considered an essential form of communication that facilitates team coordination in a rapidly changing virtual environment [2]. In particular, visual communicating functionality provided by multiplayer games is an approach to make up for the lack of non-verbal communication in online environments. For instance the ping system, a non-verbal communicative alert offered by League of Legends, transfers information by allowing players to mark a location or object on a shared visual environment in-game [36].

We see multiplayer online gaming as a suitable platform and context to better explore and understand how people perceive human-AI teaming and what they expect from AI teammates. Our choice is grounded on the unique features of multiplayer online games (e.g., dynamic game flow, high-complexity environment, various collaborative activities). These unique features of multiplayer online gaming contexts enable humans and AI teammates to collaborate and coordinate at a high level to complete complex teamwork. Moreover, in contrast to other domains, it is more feasible to design and apply AI in multiplayer online games due to the technological attributes of online games.

3 STUDY 1

Study 1 was a survey study focused on exploring people's attitudes toward AI and their preferred features of AI teammates in the context of multiplayer games. The goals of this study were to: (1) measure participants' attitudes toward AI, collaboration experience with humans, their motivation of playing games, as well as their understanding of AI technologies via five-point Likert scale; (2) collect people's preferred features of AI teammates; and (3) seek factors that were related to people's willingness to be involved in human-AI teaming.

3.1 Method

Two hundred and ninety-one participants were recruited through Amazon Mechanical Turk to investigate people's perceptions and expectations of AI teammates in human-AI teaming. Participants were paid \$1 for their participation in the survey [54]. Restrictions were set to ensure the quality of the data: (1) recruited participants were located in the United States [30]; (2) recruited participants had higher than 90% HIT (one completed task from a participant on MTurk) approval rate for all requesters' HITs [51]. In addition, attention check questions were used to make sure responses were given by humans rather than bots [49]. To ensure participants were qualified for participating in our study, one question was asked at the beginning of the survey (*Do you have experience playing team-based video games? Examples such as League of Legends, Counter Strike, Overwatch, DoTA, etc.*). Participants who chose "no" were directly led to the end of the survey. Overall, 213 participants (70 females, 143 males) were used as our final sample, excluding participants who failed any attention check questions. The age range of participants was 19 to 72 years old, with an average of 32 years old.

The survey included 67 questions in total. The average length of completing the survey was 10 minutes and 58 seconds. Participants were first asked about what games they played before and how long they had been playing online video games. Then participants were asked about their collaboration experience in video games, collaboration experience offline, and their previous

experience with AI. The third part of our survey was related to participants' motivation to play online video games. Participants' attitude toward AI was measured using a 13-question scale created by Gallup, Northeastern University. Finally, the last section focused on how people perceive human-AI collaboration in team-based video games (e.g., *"If my AI teammate is able to help me win the game, I'd like to collaborate with the AI instead of an unknown human player."*, *"If I collaborate with an AI in a video game, I don't want the AI teammate to lead the game (tell me what to do or give me commands) even if we could win the game."*). Before the first appearance of the term "AI" in the survey, a pre-definition was provided as follows:

Artificial intelligence (used as AI in following questions) is being defined as "The ability of a machine or a computer program to think and learn. The concept of artificial intelligence is based on the idea of building machines capable of thinking, acting, and learning like humans". A very common example of artificial intelligence would be Siri or Google Assistant.

This survey included both closed-ended questions and open-ended questions. For closed-ended questions, there were two types of responses: (1) responses for perception and motivation questions were rated on a five-point Likert scale from *Strongly Disagree (SD)* to *Strongly Agree (SA)* (or *all the time to none* for gameplay frequency questions); (2) for questions related to people's specific preference on human-AI collaboration (e.g., *"What type of team-based activities are you willing to conduct with AI teammates?"*, *"Which of the following characteristics of an AI teammate is most important to you if you team up with an AI teammate in a video game?"*), answers were provided in multiple-answer formatting (e.g., *Back-up/Support; Attack; Defense; Information Collection; Collective Decision-Making; Others, specify*) which asked participants to choose one option or all that apply.

League of Legends (23.08%) and Fortnite (23.30%) were the most popular multiplayer online games our participants played, followed by Counter-Strike: Global Offensive (CS:GO) (19.78%), Starcraft II (13.84%), and Dota (Defense of the Ancients) (13.85%). 7.25% of participants specified other multiplayer online games they played before, such as Call of Duty, Overwatch, World of Warcraft, and Battlefield. 96.24% of participants reported they had been playing online video games for more than a year, and 46.01% had been playing for more than ten years. 6.1% of participants usually spent less than one hour playing games per week, 36.15% of them spent one to five hours, 26.29% spent five to ten hours, and 9.85% spent 20 hours or more on games each week. Strategy game (26.25%) was reported as participants' favorite type of game, followed by Sports (21.72%), First Person Shooter (16.71%), MMORPGs (Massively multiplayer online role-playing games) (16.47%), MOBA (Multiplayer online battle arena) (15.51%), and other types (e.g., Role-playing games and Action role-playing games). To analyze our survey data, we used basic statistical methods and linear regression models to investigate what factors were related to whether people were willing to collaborate with AI teammates in games. Participants' motivation to play games, their pre-existing attitude toward AI, and their previous collaboration experience with either humans or AI were used as independent variables, and their willingness to team up with AI was used as a dependent variable.

3.2 Results

3.2.1 Preferred characteristics of AI Teammates. Our survey data showed that most human players expected their AI teammates to demonstrate instrumental skills to complete collaborative game tasks in multiplayer games. As shown in Figure 1, 48% of participants considered the possession of skills for game tasks as the most important characteristic of an AI teammate in human-AI teaming in a multiplayer game, followed by supportive (25%), proactive (14%), and obeying (following

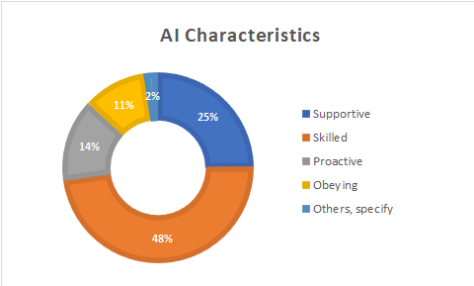


Fig. 1. AI characteristic preference distribution

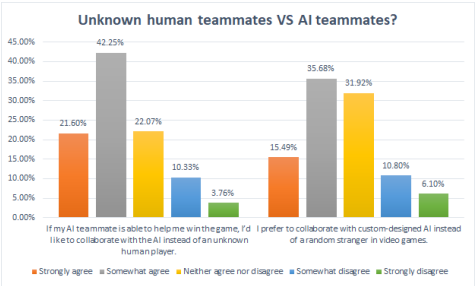


Fig. 2. Unknown Human VS. AI teammate

Table 1. Questions Used to Measure Understandings of AI and Response Distribution

Questions	SA	A	N	D	SD
Q1. If my AI teammate is able to explain its actions, it is helpful to the team performance.	40.38%	39.91%	12.21%	6.10%	1.41%
Q2. If my AI teammate is able to explain its decision-making process, it's helpful to the team performance	44.13%	35.21%	15.96%	1.88%	2.82%
Q3. AI teammates should effectively anticipate human teammates' needs.	27.70%	43.19%	19.72%	7.51%	1.88%
Q4. AI teammates should caution other team members about crucial situations.	37.09%	39.44%	15.96%	7.04%	0.47%
Q5. AI teammates should provide feedback which can promote positive interactions and future change.	38.97%	40.85%	16.43%	2.35%	1.41%
Q6. If AI knows game specific knowledge and vocabulary, it would be helpful to our communication.	50.23%	30.52%	16.90%	1.88%	0.47%

commands) (11%). This revealed the importance of gameplay relevant skills in the multiplayer game context.

It should be noted that a higher percentage of participant selected *Strongly Agree* or *Somewhat Agree* for the statement "If my AI teammate is able to help me win the game, I'd like to collaborate with the AI instead of an unknown human player" than another statement "I prefer to collaborate with custom-designed AI instead of a random stranger in video games", as shown in Figure 2, which indicates participants' eagerness to win with AI's assistance.

Especially, participants showed a clear preference for AI abilities and features based on their understanding and expectations of AI teammates. Table 1 displays questions related to the various features of AI teammates and percentages of participants' responses. More than 80% of survey participants believed that the explainability of AI's actions could enhance their team performance (Q1). Yet compared to the explainability of AI's actions, more participants strongly agreed (44.13%) that collaborating with AI teammates which were able to explain their decision-making behaviors (Q2) could lead to a better team performance than AIs which could explain their every action (40.38%). One explanation for this result is that unnecessary explanations during gameplay may cause frustrating feelings and distract human players in a competitive game. In addition, participants expressed their anticipation of AI's situation awareness in gameplay: around 70% of participants considered that AI was expected to develop an understanding of human players' needs (Q3), indicating that AI should have a shared understanding of human players as well as awareness of

Table 2. Willingness to Team with AIs in Multiplayer Online Games

	Coefficient	Std. Error	t value	Pr(> t)
Pre-existing Attitudes Toward AI	-2.61616	0.47717	-5.483	1.21e-07 ***
Understanding of AI	0.95451	0.14234	6.706	1.85e-10 ***
Previous Collaboration Experience	0.15921	0.11542	1.379	0.169
Motivation of Playing Video Games	0.20616	0.09376	2.199	0.029 *
Motivation of Playing Video Games	-0.17651	0.15706	-1.124	0.262
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Multiple R-squared: 0.3458, Adjusted R-squared: 0.3332				
F-statistic: 27.48 on 4 and 208 DF, p-value: < 2.2e-16				

the rapidly changing situations in multiplayer games. However, compared to other features of AI that were provided in the survey (e.g., explainability of decisions, mastering game knowledge), AI's capability of anticipating teammates' behaviors and needs were less expected by participants (27.70%). One possible reason for this result could be that participants considered anticipation behavior as overly difficult for an AI to conduct. More than 50% of participants strongly agreed that AI knowing game specific knowledge would facilitate their communication (Q6). This indicates that people's expectations of AI teammates are highly context-dependent.

3.2.2 Factors related to people's willingness to team with AI. In order to understand factors that have a significant influence on people's willingness to collaborate with AI in human-AI teams, we built linear regression models to examine the relationship between people's previous experience and attitude and their willingness to collaborate with AI. The independent variables were participants' pre-existing attitudes toward AI, understanding of AI, previous collaboration experience (with humans), and motivations to play games. The dependent variable was people's willingness to be involved in human-AI teaming in multiplayer video games. We first built three models including gender, age, and gender and age, along with four independent variables. Given the results that age and gender had no significant influence on people's willingness to collaborate with AI, we decided to use a model with four independent variables as predictors.

The first independent variable **Pre-existing Attitudes Toward AI** was measured through eight questions (e.g., "Overall, AI will have a mostly positive impact on how people work and live in the next 10 years"; "To protect consumers, the federal government should do more to regulate companies that use AI.") ($\alpha = 0.71$). We selected six questions to measure participants' **Understanding of AI** (e.g., "AI teammates should effectively anticipate human teammates' needs"; "AI teammates should caution other team members about crucial situations.") ($\alpha = 0.83$). The third independent variable, **Previous Collaboration Experience**, was measured via three questions (e.g., "How much do you enjoy working on a team in your study or work?"; "I collaborate with people a lot in my study/work.") ($\alpha = 0.7$). **Motivation of Playing Video Games** was measured with nine questions (e.g., "What do you think about competing with other players in online games?"; "What do you think about dominating/killing other players in online games?"; "What do you think about exploring every map or zone in the world?") ($\alpha = 0.76$). The dependent variable **people's willingness to be involved in human-AI teaming** was measured using the question "If I have a chance to team up with AI in a team-based online game, I'd like to try it.". Table 2 shows the linear regression model result.

The linear regression model with four predictors explained 34.58% of the variance, $F(4, 208) = 27.48$, $p < 2.2e - 16$, adjusted $R^2 = 0.33$. This indicates that participants' pre-existing attitudes toward AI, understanding of AI, previous collaboration experience (with humans), and motivations

to play games can explain 35% of their willingness to team up with AIs in gaming. Among the four independent variables, both *Pre-existing Attitudes Toward AI* ($p = 1.85e - 10$) and *Previous Collaboration Experience* ($p = 0.029$) have significant correlations with people's willingness to collaborate with AI. This matches our basic understanding of the influences of previous experience on decision-making [26]. Moreover, it indicates the importance of initial collaborative experience with AI.

In summary, our survey first examined the factors influencing people's willingness to collaborate with AI teammates. Our quantitative research results showed that people's attitudes toward AI and previous collaboration experience with humans, both measured by a five-point Likert scale, were significantly correlated with how willing they were to team with AI teammates in multiplayer online games. It should be noted that people expected AI to function like a real teammate in gameplay, such as providing support or exchanging information proactively. We then investigated people's preferences for team-based activities, as well as features they expected AI to be equipped with in human-AI teaming. Being skilled to complete game tasks were considered the most important attribute of an AI teammate, when compared to being supportive, being proactive, and obeying.

4 STUDY 2

Study 1 aimed to examine factors related to people's willingness to collaborate and coordinate with AI in highly complex environments, and explore people's preferred features of AI teammates. We found that pre-existing attitudes toward AI and previous collaboration experience were correlated with people's willingness to team up with AI teammates and instrumental skills were the most favored attribute of AI teammates. Grounded on the insights from study 1, we conducted a qualitative follow-up study focused on interviewing people to further explore their expectations of AI at a *team* level. In addition, we investigated people's current perceptions of AI to examine the relation between these perceptions and their expectations of AI teammates.

4.1 Method

On the basis of survey results, twenty participants were recruited for follow-up interviews to further explore how people desire AI teammates to perform as a real teammate in multiplayer online games. We used several platforms to recruit participants. Recruiting announcements were posted in Facebook esports groups, Reddit, and esports Clubs. We used "esports plus university name" as keywords to find university esports groups via Facebook. A recruitment post was shared with esports club members of a US university. In addition, we contacted game players who we already knew to invite them to participate in our study via a snowball sampling method.

Participants were interviewed through Discord, phone call, or face-to-face. Eleven questions were asked to understand what people anticipate and expect from AI teammates in team-based game activities (e.g., "*What kind of improvement in AI do you think would promote human-AI collaboration in your experience?*"; "*What's your dream AI teammate like in online video games? What do you expect from an AI teammate?*"). The average length of interviews was around 30 minutes. Since we were interested in people's perceptions of current AI teammates, as well as their expectations of AI teammates based on this understanding, we did not provide a predetermined definition of AI during the interview to avoid any bias imposed by the researchers. In contrast, we provided a specific definition of AI in the survey study, because it was necessary and critical to measure participants' understanding of AI without confounding variables (e.g., various understandings of AI). Participants were aged from 18 to 31 and all located in North America. Table 3 presents the demographic information of the interviewees.

We used qualitative analysis based on grounded theory [18] to explore how people expect AI teammates to perform in human-AI teaming in multiplayer games. The interview was coded

Table 3. Demographic Information of Interviewees

ID	Gender	Age	Location	Occupation	Multiplayer Online Games Played
P1	Male	18	USA	Student	LoL
P2	Male	22	USA	Student	Dota
P3	Male	21	USA	Student	LoL
P4	Male	30	USA	Student	FIFA; CS: GO
P5	Male	31	Canada	Software Engineer	CoD
P6	Male	22	USA	Student	CS:GO; DOTA 2; FIFA; LoL; Starcraft
P7	Male	23	USA	Student	DOTA 2; Apex Legends; Overwatch; Starcraft
P8	Male	19	USA	Student	PUBG
P9	Male	30	USA	Biologist	DOTA 2; CoD; CS:GO; Fortnite; Apex Legends; Starcraft 2
P10	Male	22	USA	Student	LoL; CS:GO
P11	Male	22	USA	Student	LoL; RB6S
P12	Male	23	USA	Student	Hearthstone
P13	Male	25	USA	In between jobs	Apex Legends; CoD; Fortnite; Overwatch; Clash Royale
P14	Male	25	USA	Healthcare employee	CoD; Diablo
P15	Male	24	USA	Artist	RB6S; CS:GO
P16	Male	25	Canada	Clinical Researcher	LoL; CoD; Super Mario
P17	Male	22	USA	Student	Wargame: Red Dragon; War Thunder; Tribes: Ascend; Overwatch; Combat Arms; Titanfall 2; Rocket League; RB6S; World of Tanks
P18	Male	23	USA	Software Engineer	LoL; CS:GO; Overwatch
P19	Male	24	USA	Student	LoL
P20	Male	30	USA	Student	CS:GO; CoD; FIFA

Call of Duty (CoD); Counter Strike: Global Offensive (CS:GO); PlayerUnknown's Battlegrounds (PUBG); League of Legends (LoL); Rainbow Six Siege (RB6S).

following four steps: (1) the first author read through all the transcriptions of interviews to obtain a basic understanding of people's perceptions of human-AI teaming; (2) the first author summarized main themes based on participants' narratives of their previous collaboration experience with AI and their expectations of future AI teammate; (3) all authors discussed and refined themes to make sure participants' expectation were completely understood and summarized; (4) the first author re-read all narratives and extracted quotes based on identified themes and sub-themes; (5) all authors further discussed and refined themes and sub-themes to generate an integrated understanding of people's perceptions of current AIs and their expectations of AI teammates based on these perceptions in the context of multiplayer games.

4.2 Findings

In this section, we present our findings as two parts: participants' perceptions of current AI teammates in games; and their expectations of AI *teammates* based on their understanding of current AI techniques.

4.2.1 Perceptions of current AI teammates. Based on our interview data, we categorized people's perceptions of current AIs into negative and positive perceptions. This mixed feeling toward AI teammates may be due to individual differences and various collaboration experiences. Given the diversity of games in which participants have different collaboration experiences with AI teammates, people's perceptions may be influenced by the AI teammate they teamed up with in a specific game. Another theme that emerged was AI being considered as a tool.

Both negative and positive perceptions. Multiplayer online games offer a complex competitive environment and involve various highly complex tasks, which require all teammates to

collaborate closely with each other. However, current AI is often incapable of adequately demonstrating all necessary characteristics of being a teammate. Some participants expressed their negative perceptions of AI due to its low-intelligent level in games:

I collaborated with AI, and it was not fun. AIs were dumb. If I'm playing multiplayer games, my whole goal is not to have any AI in the game. (P4, male, 30)

Most of the cases, AI's are not very intelligent. (P5, male, 31)

Most AI today, in my opinion, is just trash garbage and doesn't make the right plays. It is more of a hindrance. (P13, male, 25)

As shown in the quotes, P4, P5 and P13 all showed resistance against collaborating with AI because AIs were not fully capable of performing high-level complex collaboration with human players, which participants indicated led to dull collaboration experiences. According to all the quotes above, the mismatch between AI's role in gameplay (i.e., teammates of human players) and AI's capabilities made it difficult or impossible for human players and AI to collaborate and coordinate with each other, thus generated negative emotions for human players.

In contrast, some participants presented their positive perceptions toward collaborating with AI. For instance, P20 (male, 30) pointed out the improvement of AI design in a multiplayer game FIFA:

In FIFA, or football, the computers have gotten better. They become more unpredictable. They play football like football. The computer is now doing more realistic things or more unpredictable things, which is more realistic. In this aspect, AI is actually improving the state of the art.

According to P20, the unpredictability of AIs made them one step closer to being AI teammates capable of exhibiting teamwork behavior. Another interviewee also discussed his positive perception of current intelligent AIs:

One thing interesting to look at is Dota AI, Open AI. Ages ago, the Dota team did it just for one AI versus one AI. Recently they came out with a full team. And it's been absolute trashing people. They've actually gotten this team of all AI to work together. And it's just absolutely fascinating seeing how they take every engagement and just know what to do like three steps ahead and how they never make a mistake. (P8, male, 19)

P8 showed his eagerness for collaborating with high-performance AI teammates, i.e., the AI developed in OpenAI Five. OpenAI Five was a machine learning project aimed at creating a full AI team to compete against human teams. P8 emphasized two crucial features of OpenAI, *being capable of predicting gameplay* and *stable performance without making mistakes*. He highlighted how Open AI was "treated" as a subject with independent "thoughts" with the phrases "take every engagement" and "know what to do". This also indicated the difference between AI teammates and AI as a tool: AI teammates were capable of generating their own "thoughts" based on the information (data) they access.

In the multiplayer game domain, current AI are often not equipped with capabilities to work on high-complexity activities with human players, such as giving responses to human players according to teammate needs in specific situations or assisting human players with expected support. According to our interview data, people's perceptions of AIs (negative or positive) were shaped by the development and implementation of AIs in gaming.

AI is a tool. As previously noted, current AI is not capable of functioning as a full fledged teammate (exhibiting traditional human teaming behaviors) due to the complex and rapidly changing collaborative environment. For this reason, some interviewees expressed that they considered AI as a tool not impacting game outcomes. For example, P17 believed AI was a tool in Arma gameplay:

I've had AI teammates in Arma. Arma is a shooter game. It's more of a military sandbox game. You have access to different AI, setting up a team, just however you want to have the maps. So you're on a team with AI fighting other people with AI teammates as well. [...] I'd say it was neither enjoyable to collaborate with AIs nor not enjoyable. AI can be irrelevant. They're a tool. If you view them as a tool, it doesn't really matter. (P17, male, 22)

From P17's narrative, the AI that human players could choose and control in Arma was perceived as a tool rather than a teammate even though he used the word "AI teammate" at the beginning. For him, the AI was designed, built, and presented to players in Arma as a tool to utilize which affected his perception of AI: AI was a tool.

P7 (male, 23) described his similar perception of AI in games:

I did actually, just last week, play with AI on a team, as well as with two humans in League of Legends. I play with one AI on my team more often in Starcraft. So this is gonna be a "one in one" sort of thing. Oftentimes, they'd be sort of role-playing games, like a Dragon Age. You have your party members and they do their own things while you control your own. Or like a Skyrim, with your companions and so on. Sometimes I am able to tell them what to do. Other times you don't really collaborate with them whatsoever and they just do their own thing.

As highlighted by P7, AI in some real-time strategy (RTS) games had their own rigid, pre-defined responsibilities, leading to less collaborative activities between AI and human players compared to some other games. His perception of AI (i.e., "AI was a tool and should be commanded to complete their responsibilities") was shown in his other narratives as well:

In terms of if I could control all of them. Yeah, I would like to collaborate with them. That would work better as teams. Maybe not as games, but as teams. (P7)

P7 emphasized that teaming up with an obeying AI teammate might work better in terms of teams, but it would be at the cost of team performance. Teaming with controlled AIs was less likely to have any team conflicts due to the obeying feature. In this sense, the only subject who was capable of independent thinking and decision-making was the human player. Most multiplayer online games require players to team up with a fixed-number of team members. For this reason, some AI were used to fill in the empty position in a team to make sure human players were able to start a game session. For instance, P8 highlighted the goal of filled-in AI tools:

Such as leagues of legends I've played. They have the bots but they don't affect the game. What the bots do there is mainly being there. And that's the thing. (P8, male, 19)

The perception of AI as a tool was affected by the setting of AI in gameplay. Human players joined the game and were "forced" to accept the participation of AI. Specifically, as P8 pointed out, the goal of AI being in this context was simply to be a fill-in tool or unfulfilling replacement for human collaborators. This setting of the current implementation of AI in the gaming context influenced his perception of AI.

In summary, our interviewees highlighted previous experiences of collaborating with AI as a key factor in shaping their perceptions and expectations of human-AI teaming. Furthermore, people's expectations of AI teammates are based on their current perceptions.

4.2.2 Expectations for AI teammates in human-AI teams. Due to the fast-paced feature of competitive multiplayer online games, team members have to adapt to the team's needs and modify their actions rapidly as the game proceeds. Especially, our participants highlighted four main expectations for their AI teammates to achieve high team performance in such time-sensitive virtual environments:

advanced instrumental skills for completing high-complexity tasks, shared understandings of human teammates, sophisticated communication abilities for information update, and human-like behaviors.

Instrumental Skills. In the context of multiplayer online games, each team member's skills for completing game tasks are crucial to high team performance. In human-AI teaming, the AI's skill level should be comparable to human's such that humans and AIs could collaborate at a team level. Based on our interview data, instrumental skills was identified as an important expectation of AI teammates. For example, participants highlighted that an AI teammate should be able to offer guidance, help, and assistance for their gameplay:

A dream AI teammate may be some AI which is way better than me and which should actually help me play better, and help guide me play a better catch. So it's not just like the same level as me, but a bit better than me and can communicate with me really well, and can help me play the game. For example, when I play chess, I can have an AI actually tell me which move will be better, like this move has a better percentage of chances of winning, so I'm actually learning by playing. (P6, male, 22)

According to P6, an AI teammate was expected to help and guide him during gameplay similar to a human coach. The hope was that AI could provide the human players with clues about the best strategy to play or even win the game, which also helped the human players learn and improve themselves. Compared to merely watching live streaming or gaming videos, interacting and practicing with AI in an immersive environment may make human players better recall what strategy they should follow in specific gaming scenarios in the future.

Interviewees also pointed out that they expected AI to possess mechanically perfect skills to carry out their assigned roles immaculately:

I would say that I would look for it mechanically perfect in its role. Because it's an AI, that is fine that it would mechanically perform on a micro. It's the most efficient job that it can as we all strive to on our micro play. I would say I would seek perfection just because that's what human players strive for. (P10, male, 22)

What I expect from them, like in my game in general, is just to be better mechanically, not the most perfect machine, technically player. (P1, male, 18)

For P10, AI should handle the tasks which are difficult or impossible for humans to complete. He also showed that he treated AI teammates differently from human teammates due to AI's machine nature. In this sense, he expected AI to make no mistakes in performing its responsibilities. P1, in contrast to P10's "perfect machine" expectation, simply expected AI to possess skills better than himself, rather than a perfect machine.

Thus, "being perfect" was not the absolute criterion. Rather, some interviewees expected that AI could perform just better than them instead of being perfect (e.g., "*a bit better than me*" (P6, male, 22); "*not the most perfect machine, technically player*" (P1, male, 18)). In addition, what players considered as "better" was determined by how they collaborated with the AI and by the specific context (e.g., what team-based game they expected to collaborate with the AI in). However, despite the high expectation for AI teammates to possess advanced instrumental skills for in-game tasks, P16 (male, 25) revealed deficiencies of AI that cannot be compensated for with high-skill performance:

However, I definitely think that kind of give-and-take of personality features that what would be lost is kind of that camaraderie, that sense of like, buddy-buddy ness, because they would just be a very effective, it would be a tool now that they're just reporting information and you're reporting back a plan and they're executing, they're

following it or they're offering a plan back and you're executing and following it. So it'd be very mechanical, versus that kind of that human element, e.g., planning and logistics of making plans and formations off of humans' experiences and knowledge.

P16 emphasized a major limitation of AI teammates - the lack of human factors. Humans can socialize in games to make friends and each player has their unique play style and personality traits. These unique characteristics make it enjoyable and socially satisfying to team up with other human players. In contrast, AI have their unique "superpower" (e.g., stable performance, high-accuracy predictions of game flow) due to AI's algorithmic nature, which humans do not possess. Therefore, although AI teammates are unable to make high-level situational decisions or perform with the level of spontaneity associated with humans, AI can still fill its own niche as a teammate in future human-AI teaming with its instrumental skills as an advantage.

A Familiar AI, Not an Unknown AI. Instrumental skill was mentioned as the top expectation in participants' narratives, followed by shared understandings of AI teammates (e.g., being familiar with the AI). Within our human-AI teaming context, being familiar refers to having a basic understanding of the AI, such as knowing what an AI's actions might be under specific scenarios. Much can be learned from human-human teaming with regard to team familiarity. The development of team cognition plays an important role in human-human teaming [9]. Shared understanding, as a core component of team cognition, enables teams to collect and organize related information in a collective way [22]. In multiplayer games, a shared understanding of teammates has a significant impact on team performance and team efficiency since a shared understanding of human teammates facilitates tacit coordination [17]. This shared understanding can be envisioned between human players and AI teammates as well (i.e., AI can anticipate human teammates' actions in a rapidly changing game environment and perform accordingly).

The dynamic game flow, various collaboration scenarios, and different types of collaborative tasks, such as information collection, real-time information sharing, and decision-making, force human players to perform with anticipation of their teammates' actions in mind. To do so, each player has to develop an understanding of their teammates so as to predict other teammates' actions under a specific situation. Similar to human-human collaboration, an understanding of AI teammates is necessary to achieve high team performance. For example:

So you are one player, but the other four are computers. And the problem in that one was that they had certain strategies, preset strategies that they just used to follow that they were all doing the same thing. But maybe I wasn't in sync with that much. So that was more difficult experience for me because the strategies weren't matching. I was thinking in a different way. And they were thinking in a different way or they were acting in a different way. So it depends on how the game developers will build the AI. (P20, male, 30)

As P20 revealed, without a shared understanding of AI teammates he would not know what strategy the AI would make, which may result in a conflict between human players and AIs. P20 also described the other four computers (AI) as 'they' and assumed that the four AIs had a shared understanding as a team without him. This kind of 'I' versus 'they' seemed to reflect his different perceptions and treatment of AIs compared to human players.

P14 (male, 25) and P16 (male, 25) expressed similar thoughts:

I think there is a little bit of shared cognition to a certain extent. There's a certain mode you can set them to a follow mode, which means they'll follow you on the map to certain objectives and they'll cover you and defend you against other Titans or pilots. (P16)

If you're moving to a mission, you have to do certain things at certain points. For example, I'm moving through a street with a friend of mine and I know that there's going to be a sniper up on the left balcony. And I know my teammate is covering that balcony so I know I'm safe. With an AI you don't know that because you don't know what it is gonna do. A human teammate learns your play strategy and you learn his/her play strategy so you know where to cover that person, and that person knows where to cover you. I don't know if we have that developed yet with AI to know that, so that I don't have to worry about going over there because I know the AI is going to cover there. (P14)

P16 described his ideal AI teammate as being able to understand his words and knowing how to support and protect him according to his actions during gameplay. This required AI to develop a shared understanding of P16 (e.g., his play style) and game tasks to anticipate his behaviors in changing scenarios. P14 explained how to ideally collaborate with AI in a specific scenario. Only when he had a shared understanding of the AI teammate, i.e., knowing what his AI teammate would do in a specific situation, was he able to react to the dynamic game scenario based on his anticipation of the AI's behavior. In particular, P14's expectation of AI teammates came from his experience with human-human teaming in collaborative games. He especially pointed out that the possession of a shared understanding of AI teammates reduced his concern regarding the AI's behavior in a gaming session, which was the same as how collaboration worked in his prior human-human teams. In other words, trust can be built between humans and AI with a shared understanding of the AI teammate.

P14 was not the only interviewee who mentioned that human players could trust AI with a shared understanding of AI teammates. P17 (male, 22) also mentioned,

You have to learn AI's behavior, what their normal behavior is and then you can trust it to do as like you know the AI will generally do this and you can trust it to do that, because you've seen it happen so many times.

In summary, these quotes collectively describe how human players expected to develop a shared understanding with AI teammates in the context of multiplayer gaming. In human-human teaming, players need to practice with teammates over time to develop a shared understanding of teammates. Sometimes, professional players even need to get along with each other outside of the game in order to build the shared understanding. However, game AI is incapable of interacting with humans outside of the game environment. As a result, understanding the development of shared understanding between human players and AI within the context is critical for designing for future human-AI teaming. This understanding is important not only in gaming, but also in any domain where high-level collaborations are required between humans and AI teammates.

Various Communication Strategies. Communication is a core element of teamwork as the interdependence feature of teams requires team members to coordinate and collaborate together. Multiplayer games, as dynamic collaborative systems, often force team members to share information accurately and rapidly. However, communication is a challenging issue in human-AI teaming. Considering the difficulty of building communication channels between human teammates and AIs, some games do not provide any communication functionality between human players and AI, as P14 (male, 25) pointed out:

When I teamed up with AI, it was a lot harder than with human players. So it'll usually be objective- or mission-based type of thing. You have AI, but you don't have any communication to control the AI. The AI just does what it wants.

As P14 mentioned, without communication, collaboration in a human-AI team was more like a sum of individual work without team-level work. However, this kind of teamwork was not real

collaboration, which required teammates to coordinate closely with each other [8]. To address this issue, participants expected that they could share and exchange information with their AI teammates in a variety of ways, such as natural language processing, a ping system, or even indirect communication. For example, some interviewees desired to communicate with AI via natural language:

One way to improve human-AI communication will be making them to understand normal human language, like I get somebody to say like "go", "fall back", or something like that. In Counter-Strike, they should be able to understand how to stick with me or something like that. If I say "follow me", the AI would just follow me. (P2, male, 22)

Your only real communication, at least in a lot of games, is through word of mouth because you're doing so many other tasks. So ideally, you can communicate with it through speech. (P12, male, 23)

A feature of the game was that you used voice communication to move combat units around in a real-time strategy game. So in terms of ideal ways of communicating, voice would be easiest because it doesn't interrupt gameplay. (P16, male, 25)

P2 described an ideal scenario where human players could command AI by talking to the AI. As shown in his narrative, the communication in natural language between human players and AI should be pretty simple (e.g., "go", "fall back"). This could reduce the difficulty of communication challenges in human-AI teaming to some extent. As highlighted by P12 and P16, in a rapidly changing and competitive game environment, voice communication was the best and easiest way to communicate with other teammates. The reason was that most competitive games had time constraints and players needed to focus on gameplay rather than communication. Moreover, voice communication could keep the game flow going smoothly. Therefore, a communication strategy that takes little effort for the human players to interact with AI teammates should be considered in human-AI communication design.

However, participants expressed different opinions on whether such communication should be two-way or one-way, for example:

That would be really cool if I could speak with the AI and they would understand and speak back. (P15, male, 24)

I think voice commands would be really good. (P13, male, 25)

As pointed out by P15, communication with AI should have two directions: humans could talk to AI and AI should be able to understand natural language and speak back to the human. However, P13 described the communication with AI as one-direction - only needing a human to talk to the AI; the AI would need to understand what he said and follow his commands with no need to speak back. He also used the word "voice command" rather than "voice communication" or "voice discussion". In this sense, he seemed to expect that he could command AI via natural language similar to how people asked Echo to play music or check the weather. P14 (male, 25) shared a similar expectation:

The ideal communication would be just talking to it and helping it understand. For example, I can say, "Hey look, when we clear this building", or "I need you to clear the rooms on the right and I'll clear the rooms on the left".

As elaborated by P14, the goal of having communication in human-AI teaming was to help the AI better understand human players' instructions. From P13 and P14's quotes, they expected to utilize such one-direction communication to command AI as a tool or an obeying teammate.

Ping communication is another expected way to communicate with AI teammates. Compared to voice communication via natural language, ping communication utilizes visual markers to

help players exchange information in a simplified way. This non-verbal communication is more direct and less distracting for players to share information, especially location information. Some interviewees expressed their preference for ping rather than voice to communicate with AIs:

So it would be cool if they could react to humans. For example, you can say "go here, ping and this", so they can kind of follow your orders, or say, "is there an enemy over here", so they can look in, like set in that direction. I think that would be so sort of helpful. I think ping would be more practical compared to voice communication. I don't know if voice communication would be necessarily better. (P7, male, 23)

Pinging would be pretty ideal because even when I play with human teammates, I don't really like to communicate much with my team through voice or text chat. It's just occasional. Communication is usually done through pings. (P18, male, 23)

According to these quotes, ping communication, or visual communication, required less effort than voice communication to receive and understand the shared information. This helped players focus more on game tasks. In addition, ping communication was more direct and clear for players to share location information. For games where location information mattered, ping communication was notably beneficial. Therefore, when developers and designers create communication features for human-AI teams, the most appropriate way to communicate should depend on the specific task or environment.

Human-like AI. We understand human-like AI as AI with human-like behaviors and performance. As we explained earlier in this paper, human expectations of AI teammates are often built upon their pre-existing attitudes toward AI and experience with other humans. As a result, when being asked what their expectations of AI teammates were, some interviewees described a dream AI teammate as a human-like AI:

AIs should behave like humans. (P5, male, 31)

The ultimate AI has to be like as close as a human, like you can interact with it, like it has to be from sci-fi. Like say, if you watch Star Wars a lot, it might be something like that. Even that AI was predictable, but it would be more human-like. (P4, male, 30)

Both P4 and P5 pointed out that AI should be human-like, even if it was predictable. In a previous response regarding his previous human-AI collaboration experience, P4 indicated a strong negative attitude toward how current AI was often predictable and how boring it was to collaborate with in-game. However, he still considered human-like the most important feature of his ideal AI teammate. As mentioned by P4, the AI in Star Wars were not very intelligent, but could interact with humans like a human being, even though they are not humanoid. In other words, he expected that human-AI interaction would be close to human-human interaction.

In addition to human-like interaction, AI is also anticipated to carry out tasks as well as humans, so humans can team up with AI as an alternative:

Preferably you would want an AI that performs just as well as a human that you can rely upon and that you can communicate information effectively with, but at the same time, you don't want an AI to replace the human in a multiplayer online game that would interrupt the flow or become too difficult to face. I think AI should be supplementary for games and to not completely replace the human element. (P15, male, 24)

I think the best AI teammate that I could think of would be an AI that's capable of acting like an actual ally, someone who can see certain events happening across the

game and make decisions based on those events in a way that's comparable to a teammate that I'd be playing with. (P12, male, 23)

According to both P12 and P15, AI was expected to behave like a *real* human teammate they can rely on. However, P15 emphasized that AI should not be able to replace human players. In this sense, human players had the power to decide whether an AI teammate could join a game session or not.

In summary, four type of expectations emerged from our interview data: (1) advanced instrumental skills for close in-game collaboration and coordination with humans, (2) shared understandings of human teammates which facilitate the shape of team performance, (3) sophisticated communication abilities for information sharing, and (4) human-like behaviors for human-like interactions and performance. In particular, AI teammates are expected to possess specific game skills to complete difficult game tasks. Moreover, similar to the expectation that AI should build a shared understanding of human teammates, humans may want to develop a shared understanding of AI teammates to anticipate their behavior during gameplay. Compared to these two expectations, the anticipation of human-like AI does not originate from the nature of AI or the nature of teamwork. Rather, it comes from the imagination of humans, as well as previous experiences and habits that were developed during years of teaming experience with other human beings.

5 DISCUSSION

Using multiplayer online games as a context, we have used a survey study and a follow-up interview study to highlight: (1) people's perceptions of AI teammates include both negative and positive perceptions, and that AI is often perceived as a tool (RQ1.1); (2) people's previous collaboration experience and their pre-existing attitudes toward AI are related to their willingness to team up with AIs (RQ1.2); (3) AI teammates are expected to possess instrumental skills for in-game tasks, have a shared understanding with human teammates, be capable of communicating with humans, and perform like a human in gameplay (RQ2). In this section, we discuss how our findings support and extend the current understandings of human-AI teaming presented in CSCW. We also point to potential directions of AI design for future human-AI teaming beyond gaming.

5.1 New Perspectives of Human-AI Teaming

Previous studies on human-AI collaboration in CSCW have highlighted: 1) people have mixed feelings toward AIs [60]; 2) high-performance AIs are more likely to build trust with humans [65], which indicates better coordination and collaboration [25]; 3) shared understanding plays an important role in human-AI collaborative teamwork [23, 29]; 4) AIs are treated differently from humans [45]; and 5) AI should be considered as a subject rather than a tool in human-AI teams [60]. Our findings are consistent with these studies in terms of people's perceptions of AI, as well as people's expectations of AI. We will discuss this consistency in the following sections. In addition, we have also identified several new perspectives for human-AI teaming regarding people's expectations of human-AI teaming.

5.1.1 Perception of AIs. While previous CSCW work on human-AI teaming in CSCW has looked at data scientists' perceptions of AI systems, which stand as potential competitors to their jobs [60], our research focuses on human perceptions of AI teammates solely in a cooperative context. Specifically our research looks at this perception in terms of (1) coordination between humans and AI *teammates*, which indicates little risk to replace humans, and (2) a complex collaborative environment, which requires humans and AI teammates to exchange information, anticipate teammates' behaviors based on a shared understanding, and coordinate closely to complete high-complexity tasks in a collective way. Our findings indicate AIs should not be considered simply as a tool, but rather as a subject,

which supports previous studies in terms of AI's role in human-AI teaming [60]. Additionally, our interview data revealed unfairness in the treating of AIs compared to humans, which supports previous CSCW studies [45, 48]. In previous work, AI teammates were identified as "scapegoats" in human-AI teaming in computer games due to blame assignment [45]. Rather, in our study, the bias mainly pointed toward two aspects: (1) using 'I' versus 'they' to describe humans and AIs; (2) expecting AI to be perfect at gameplay due to their machine nature. Our qualitative research also demonstrated people have both negative and positive perceptions of human-AI teaming, which supports a previous CSCW study that noted people have mixed perceptions resulting from their prior collaboration experience with AI systems [60].

5.1.2 Diverse expectations of AI teammates in human-AI teaming. Considering very little work has focused on what humans expect from AI teammates in human-AI teaming in CSCW environments, our study extends current CSCW literature by looking at people's expectations of *human-AI teaming*. We have identified several new perspectives for human-AI teaming, including people's expectations that AI teammates should have instrumental skills for completing collaborative tasks, shared understandings of human teammates, sophisticated communication abilities for information exchange, and human-like performance. These expectations support previous teamwork studies in CSCW environments to some extent.

First, both our survey and interviews identified instrumental skills as the most preferred feature of AI teammates. This supports previous work that shows that people are more likely to trust AIs with high-performance than with low-performance [65], which indicates people and high-performance AI are more likely to coordinate and collaborate effectively [25]. From a human-AI teaming standpoint, taking use of AI's strength may outweigh barriers caused by AI's weakness (e.g., lack of human factors) due to its algorithm attributes. Therefore, an AI teammate's ability is critically important to the team.

Second, AI teammates are expected to develop a shared understanding of human teammates. This indicates the important position of shared understanding in human-AI teamwork, which supports previous CSCW studies [23, 29]. Previous research on human-AI teams has shown that developing an understanding of AI teammates helps human players better understand AI behaviors and further anticipate an AI's action as the game proceeds leading to a successful team performance in CSCW environments [29]. This finding also supports a large amount of work on human-human teaming that indicates the building of shared understanding of teammates positively influences team performance [8, 10].

Third, various communication strategies were expected by people to complete information exchange in collaboration. Compared to AI tools, our study found people desired AI teammates to receive human teammates' information, understand what to do next, and sometimes even convey information to humans. This supports previous CSCW work that suggests AI should understand and contribute to human-AI communication [40]. The most ideal communication approach is via natural language processing, which has been studied for decades and applied to conversational agents in CSCW [41].

Lastly, while previous research shows that the design of conversational agents is based on human behaviors (e.g., greeting, using normal human language style, having a personality) and appearance [33], our findings reveal human expectations for human-like AI teammates from a collaboration standpoint. In other words, our findings indicate that people also expect agents to perform like humans while collaborating with them to complete tasks. Especially, one new perspective regarding people's perception and expectations of AI teammates was that people who had negative perceptions of AI seemed to be more likely to expect the AIs to perform like a human

in multiplayer games. However, people who did not hold a negative attitude toward AI were more flexible regarding AI teammates' role and performance.

In summary, these new perspectives of people's perceptions and expectations of AI teammates contribute to/extend existing studies by exploring an emerging type of collaboration: *human-AI teaming*. Our findings provide insight for future human-AI teaming development and implementation. Understanding people's expectations of AI teammates could catalyze the development of trust and increased performance for future human-AI teams.

5.1.3 AI is not Doraemon. An interesting finding of our study indicated that humans put forth unrealistic expectations on AI teammates. For the past sixty years, AI has been developed to support/assist human beings within a variety of contexts [7, 46, 47]. Based on advanced machine learning algorithms, AI continues to be more and more intelligent, and evidence suggests that AI will be able to perform in ways in which people are not able to [60]. However, it is worth noting that AI is not Doraemon, a character in a Japanese manga with the ability to fulfill the main character's various unreasonable wishes. In other words, AI can not perform in any imagined way. We have to be aware of AI's limitations and the inevitable fact that AI is not able to perform exactly the same as humans. As discussed in section 4.2.2, human anticipations of AI partially originate from their experience with human-human collaboration in games. Many times, in the human-AI teaming context, humans seem to be perceptually replacing humans with AI while expecting the AI to exhibit all the positive qualities of humans in teaming, while also outperforming humans. As this is not realistic, human-AI teaming designers may want to focus on building an ideal AI teammate rather than creating an ideal human substitute.

5.2 Future Design Insights of Human-AI Teaming

In order to improve human-AI teaming and develop more efficient human-AI teams, one essential thing to note is that *AI matters in human-AI teaming design*. Currently, some human-AI teams are designed with the assumption that humans are the only subjects taking part in the collaboration. Though it is more simple to utilize AI only as a tool, this simplification could limit the team in high-complexity, collaborative tasks. From a human-centered perspective, we propose that AI should be considered as an individual subject and teammate in human-AI teaming design.

First, AI should be taken into account as a subject in collaborative-activity design. In contrast to using AI as a substitute for humans, designing team-based activities from the standpoint where AI and humans are considered as co-subjects and teammates may provide a more reasonable and enjoyable collaborative environment. In order to create a collaborative team, AI should be designed and implemented from a human-AI teaming perspective rather than as a fill-in or unfulfilling replacement for human teammates. Considering both AI and humans as subjects in the collaborative context is necessary and important in human-AI teaming.

Second, human-AI teaming designers may take advantage of AI's innate abilities in human-AI teaming design when considering aspects such as roles, tasks, or goals. AI's unique intrinsic feature, algorithm-based, is a key factor in human-AI teaming design. Although developing a human-like AI is the current AI design trend [12], the fact that AI lacks human factors, i.e., unable to generate emotional change, can not and should not be ignored. In contrast to adding human-factors to AI (e.g., human-like cognitive thinking ability), leaning into AI-factors (e.g., stable individual performance, high-accuracy) could be a direction of future AI design within the human-AI teaming context.

Third, human-AI teaming designers may want to create special team activities or mechanics to facilitate the development of a mutual understanding between AIs and human teammates. In human-human teams, shared understandings of teammates are generated in a natural way through time and experience. In contrast, human-AI teaming requires designers to put more effort into

building this understanding. For instance, game designers should create game mechanics to build an understanding in human-AI teams such that AI can learn human players' strengths, weaknesses, play style, and responses to specific situations.

In summary, future human-AI teaming should take AI into account to design a variety of activities (e.g., team-based tasks and various scenarios), rather than only using AI as a substitute for humans. In addition, future AI design may make use of AI's features to explore collaborative activities where AI's role is well-suited for its algorithm features.

5.3 Limitations and Future Work

One limitation of this study is that all of our interviewees were male in study 2. This interview sample might not fully represent a larger population of multiplayer online game players. Thus, the interview findings might not account for potential gender differences regarding people's expectations and perceptions toward AI in collaborative games. In future research, gender balance in the recruited sample should be considered. A second limitation of our study is that human expectations of AI teammates reported in the findings sections are heavily influenced by teamwork contexts. A user study will be used in future research to identify actual human expectations along with a specific teamwork context and controlled AI teammates. Furthermore, we hope to expand upon our findings through future research to better understand the influence of various AI characteristics and human expectations of AI on human-AI teaming. Further research on the relation between human-like expectations of AI and negative perceptions of AI will offer additional insights pertaining to human-AI teaming design.

6 CONCLUSION

Previous CSCW work generally focuses on human-collaboration and human-AI interaction, such as novel user interfaces [47] and using AI in daily work [60]. However, little work has studied human-AI teaming. In this paper, we presented results of a survey and semi-structured interviews to explore people's perceptions of AI teammates in human-AI teaming, as well as how people expect AI to perform. We found that instrumental skill was the top priority in preferred AI characteristics, based on both survey and interview results. Following instrumental skills were preferences for shared understanding between humans and AI, communication capabilities, and human-like behavior and performance. We also investigated the factors impacting people's willingness to team up with AI teammates. Both people's previous collaboration experience with humans and pre-existing attitudes toward AI were significantly related with their willingness to be involved in human-AI teams. Additionally, we propose insights of human-AI teaming design for a better collaboration and coordination in human-AI teams. This work contributes to the CSCW literature by providing an in-depth understanding of people's perceptions and expectations of AI teammates, as well as factors that impact people's willingness to team up with AI teammates.

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Received June 2020; accepted July 2020