

Leveling Up Teamwork in Esports: Understanding Team Cognition in a Dynamic Virtual Environment

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A large body of research has underscored the importance of the cognitive process of team cognition and its relation to team performance. However, little research has focused on applying such an important teamwork process to computer-mediated collaboration within a fast-paced virtual environment. In this paper, we use esports as a research platform to address this limitation due to its fast-paced nature and its heavy reliance on teamwork. We report the experience and perceptions of 20 players with regard to their descriptions of team cognition within esports. We found that esports players relied on their game experience and understanding of role interdependencies in order to develop team cognition with strangers. We also found that experienced teams utilized a mutual understanding of teammate skills and personalities in order to predict responses and limit the verbal communication required to make quick team decisions. We contribute to CSCW by extending the cognitive understanding of computer-mediated collaboration and by advancing research on team cognition and how it can occur within a fast-paced virtual environment.

CCS Concepts: • **Human-centered computing** → **Computer supported cooperative work**.

Additional Key Words and Phrases: team cognition; esports; shared understanding; shared mental model; computer-mediated collaboration

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1 INTRODUCTION

Team cognition, the cognitive processes and activities that occur in teams [19], is of interest to the CSCW community due to its implications for groupware design and collaborative systems that assist distributed teams [53, 60, 62]. As more companies explore working remote for reasons such as cost reduction, continuity planning, or environmental impacts [99], and more people find value in online collaboration for social or leisure activities [76], it is important to understand the cognitive

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aspects of distributed teamwork and how to best practice team cognition and gain common ground virtually.

Team cognition has previously been investigated, exploring important questions such as how shared understanding facilitates team cognition [20, 68], how team cognition relates to team performance [21], and how collaborative technologies can be designed to support the building of team cognition [71]. This body of research has revealed the positive effect that team cognition has on team performance [21] and the importance of designing to account for facilitating team cognition [71]. Other studies have underscored the importance of trust to teamwork as a supporting mechanism for team cognition [15, 86, 92]. Importantly, relationships between concepts such as team cognition, trust, and performance are different in virtual teams compared to normal teams [5, 11, 39, 50, 77]. However, existing CSCW studies on computer-mediated collaboration often demonstrate two limitations regarding team cognition. First, little CSCW research on computer-mediated collaboration has focused on the cognitive teamwork aspects involved. Rather, much of this work has focused on teamwork practices, communication, and design. Second, there is a lack of CSCW studies specific to team cognition within a fast-paced virtual environment, which differs from the calm and stable workplace setting that is traditionally studied in CSCW.

To address these limitations, in this paper we aim to better understand the perception and emergence of team cognition within fast-paced multiplayer online games. We believe that the fast-paced nature of multiplayer online games offers a unique opportunity to better understand the development of team cognition. Especially, we choose esports as our research context because it offers opportunities to better understand teamwork, virtual collaboration, and team cognition in an organic teamwork setting that prioritizes quick team decisions.

Multiplayer online games have proven useful for studying collaboration and teamwork in virtual environments. Many researchers find value in that multiplayer online games offer both collaboration with strangers and with friends [73]. This body of research has also revealed the importance of various forms of leadership in online games [9, 56] and the relationship to team performance [44, 52]. Other multiplayer online game studies have highlighted the importance of communication during gameplay [48] and the various ways information can be communicated in-game between teammates [8, 59, 97, 103, 104]. Still much can be learned from esports in particular due to their fast-paced and competitive nature.

Esports as a specific research platform has increasingly gained interest in the CSCW and HCI communities [72]. Part of this interest is due to the growing popularity of esports [28]. Additionally, the competitive tasks involved in esports often require players to heavily rely on collaboration and communication, which ideally result in quick and effective decision-making [29]. The nature of esports is also highly varied as it ranges from casual players who play for recreation or relaxation to professional players who make their living playing esports [28, 29]. This palette of diversity offers CSCW researchers the opportunity to study a wide array of teams. With regards to teamwork, professional esports provide an opportunity for researchers to better understand how practiced and high-performing teams collaborate using a multitude of resources such as practice facilities, coaches, and planning sessions. While on the other hand, casual esports players offer an opportunity to better understand impromptu teaming and how common ground can be established quickly within a virtual world.

Recent decades of research have revealed a better understanding of esports from many different approaches [80]. While early esports literature focused on its legitimacy as a sport [101], more recent research has explored motivations for spectating [36, 41, 91] and playing [102] esports. An inquiry line of particular interest is how these players come together to work effectively as teams. While some research has focused on team formation [30], teammate social support [29], and team

dynamics [94], very little research has focused on the cognitive teamwork processes involved in esports other than through the lens of collective intelligence [55].

Thus, in this paper, we address a cognitive research gap in CSCW on computer-mediated collaboration, specifically an understanding of team cognition within a fast-paced virtual environment, through the valuable research platform of esports. Drawing on in-depth interviews with 20 esports players, we specifically focus on the following two research questions:

- **RQ1:** How is team cognition perceived and defined in the context of a dynamic virtual environment, such as esports teaming?
- **RQ2:** How does team cognition emerge in the context of a dynamic virtual environment, such as esports teaming?

RQ1 focuses on the ways in which team cognition is understood, interpreted, and experienced by esports players in a fast-paced dynamic environment. RQ2 centers on better understanding which mechanisms, processes, and strategies esports players utilize to facilitate team cognition in esports.

Our work makes a number of contributions to CSCW and HCI. First, we extend previous CSCW research on computer-mediated collaboration by focusing on a cognitive process involved in teamwork. This perspective would further help CSCW researchers design better collaborative systems by facilitating shared understandings and coordination among teammates. Second, we contribute to the understanding of team cognition by investigating its emergence and use in a fast-paced virtual environment. This supplements existing studies of computer-mediated teamwork in a calm workplace setting. Based on our findings, we also suggest design implications for future groupware and collaborative virtual team applications that can better support the emergence and development of team cognition.

2 RELATED WORK

2.1 Teams, Team Cognition, and CSCW

High-complexity tasks today require individuals to collaborate with team members and perform in a manner single individuals cannot. In CSCW, researchers have been studying computer-supported teamwork for decades [13, 31]. Previous research has studied teams in a variety of domains, such as education [90], healthcare [43], software development [37, 38], and games [30, 55, 93]. Specifically, a body of literature has studied teams in multiplayer games from various perspectives. Broadly defined, a team is "a social entity composed of members with high task interdependence and shared and valued common goals" [23, 84]. Especially, *team cognition* has been considered a core cognitive construct in successful teamwork.

In the field of teamwork studies, *team cognition* is defined as a "cognitive activity that occurs at a team level" [18] with shared understanding (i.e., shared knowledge related to tasks and teams) as a key component to facilitate coordination and implicit communication between team members [20]. The cognitive process in teamwork requires team members to develop a shared understanding (shared cognition/ shared mental models), such that individuals can predict their teammates' behaviors under specific situations. In this way, teams can function better with the development of shared understanding as it enables members to anticipate their teammates' behavior accurately and act accordingly based on task demand and how the team will respond [68]. Furthermore, such a shared mindset empowers an individual to adapt faster to dynamic environments to be successful in the long run.

Prior studies have shown that team cognition plays an important role in high team performance. For instance, Mathieu et al. (2000) examined the relationship between shared mental models and team performance using a simulation program of a fixed-wing aircraft and found that shared team-based mental models have a positive influence on team performance [68]. Salas et al. (2004)

described how team cognition serves as a framework to guide research on factors impacting team performance [87]. McNeese et al. (2016) explored the role of team cognition in decision support for remotely piloted aircraft systems (RPAS). They concluded that team cognition can be used to facilitate collaborative activities in RPAS and collaborative technologies should be developed to support the building of team cognition [71]. Dechurch and Mesmer-Magnus (2010) examined the relationship between team cognition and team performance by organizing previous work related to teamwork using a meta-analysis approach. Based on the meta-analytic correlations results, they reported that there was a positive relationship between team cognition and team performance [21].

Beyond the influence on team performance, team cognition is also considered as a key cognitive construct in various team activities (e.g., team decision making, team coordination). Jackson et al. (1995) identified team cognition as a mediator of diversity in decision making teams [49]. As shown in previous research, the development of team cognition leads to team coordination [25]. The team structure, which is dependent on the nature of the task and the responsibility allocation of tasks, impacts the coordination prerequisites for the team and the generation of the need for communication among team members [67]. This communication "overhead" is necessary for effective team cognition [67] and can be reduced by teammates establishing common ground to attain more effective communication [14]. Developing both content and process common ground has been identified as essential for computer-supported distributed teams seeking to effectively share and coordinate [16]. The development of a shared set of expectations such as common ground [19] and shared mental models [67] contribute to the relationship between team behavior and team performance. The way team members coordinate not only involves pre-planning and communication, which constitute explicit coordination, but also the ability to anticipate team members' actions and team needs, which compose implicit coordination. Different from the mechanism of explicit coordination, implicit coordination consists of anticipation and dynamic adjustment, which team members rely on to complete coordination across various situations [81].

Also fundamental to teamwork and a supporting mechanism for team cognition is trust [15, 86, 92]. In the context of teamwork, trust can be defined as "the extent to which a person is confident in, and willing to act on the basis of, the words, actions, and decisions of another" [69]. Importantly, trust impacts performance in teams [24], performance impacts trust [50, 70], and leaders can increase team effectiveness by engendering trust [61]. Certain relationships have been identified concerning trust and teamwork such as how trust influences team commitment, perceived team support influences trust, and teamwork behaviors influence trust among team members [89]. The influence of teamwork behavior on trust is even higher in virtual teams than in ordinary teams [77]. Thus, understanding how trust influences virtual teams and how this differs from ordinary teams is an important area of study in CSCW research. Understanding trust in these contexts is especially important since trust can be challenging to establish in virtual teams [11] and can develop differently across various virtual contexts [39]. To compensate for this challenge, trust can be enhanced in virtual teams by knowing specific information and expertise about team members [12, 88]. Similarly, identifying and applying appropriate team building strategies is important for virtual teams to develop trust initially [46]. Other CSCW research has revealed insights into both cognitive trust and affective trust. For virtual teams, both internal and external monitoring reduce the relationship between cognitive trust and performance [82]. Virtual teams are also more likely to rely on cognitive trust than affective trust [50].

However, despite these studies shedding light on team-based activities and behaviors in virtual environments, the cognitive aspect of virtual teamwork is understudied. The following section describes previous studies that have been conducted in multiplayer online games, a promising context for studying teamwork in virtual environments.

2.2 Teamwork in Multiplayer Games

As computer-supported virtual teams become increasingly prevalent, teamwork in an online collaborative environment has been an important area in team research. Specifically, multiplayer online games provide opportunities for people to interact through technologies and collaborate together to achieve common in-game goals.

Diverse collaborations in multiplayer online games facilitate various gameplay goals. Collaborations in multiplayer games are either with strangers (temporary teams or pickup groups) or with friends. The diversity of collaboration increases flexibility in learning and provides enjoyable play experiences [73]. Previous work has revealed that people often prefer to play with friends rather than strangers [9]. Teams perform more effectively when team members have a moderate connection with each other [10]. Additionally, collaborating with strangers always requires team members to take extra effort on social interactions, which promotes the generation of a harmonious collaborative environment, and self-discipline to maintain the positive collaborative atmosphere [56].

In multiplayer online games leadership works as an important element of effective teamwork. Effective leaders contribute to creating strategic plans and leading teams to succeed in collaborative tasks within various multiplayer games (e.g., *League of Legends* and *World of Warcraft*) [9, 56]. Moreover, shared leadership has a positive relation with team performance in virtual teams [44]. Previous work has revealed the relation between transactional and transformational leadership and team performance in online gaming environments [52].

Additionally, communication is considered an essential component of coordination and collaboration in CSCW environments. Previous work has revealed the importance of communication in achieving high team performance during gameplay [48]. However, communication in dynamic environments is a challenging issue considering the fast-paced feature of competitive multiplayer games. Compared to text communication, which has linguistic limitations, voice communication enables players to share information quickly and enhances social interaction [97]. In addition to verbal communication, non-verbal communication is considered as a more efficient way to share specific information in special scenarios, such as gameplay within a shared visual space [59]. Importantly, tacit coordination was shown to play a larger role than verbal communication in *League of Legends* [55].

Important to successful teamwork, researchers in CSCW have been exploring the cognitive components pertaining to team performance using various approaches. For instance, Wuertz et al. (2018) described a framework for characterizing awareness cues considering perspectives such as the information the cue provides and the design dimensions that these cues require [103]. Additionally, annotations, a type of user interface element created by users to display information, are applied in gameplay to support and enhance collaboration [8, 104]. Other studies have shown how factors such as team congruency and collective intelligence are important to team performance in multiplayer online games such as *League of Legends* [54, 55].

Though much has been learned from the research context of multiplayer online team games, much can still be learned regarding team cognition and its emergence in these dynamic environments. First, existing studies in the CSCW/CHI community have generally focused on the team performance and team effectiveness of teamwork in multiplayer online games [10, 54, 55]. While the development of team cognition reflects dynamic cognitive activities and leads to high team performance, little attention has been taken to the emergence of team cognition in the context of games. Although the impact of two cognitive styles (field-dependent; field-independent) on team performance was explored, these two cognitive styles, which are referred to as the ability to retrieve visual information from the surrounding environment, are different from team cognition [78]. Second, the fast-paced

feature of multiplayer online games makes it a unique platform to explore the development of team cognition. The dynamic game flow forces players to quickly adapt to their roles and adjust their actions according to the team's needs. It is crucial and imperative for the team members to be on the same page as the game proceeds. In addition, various types of collaborations involved in multiplayer online games (e.g., decision making, information sharing, explicit and implicit communication) provide various scenarios for the emergence of team cognition. In particular, we choose esports, an emerging context of competitive multiplayer online gaming, as our research site.

2.3 Esports

While the term *esports* has been highly discussed over the years, existing literature shows little consistency regarding its definition [28, 29, 98]. Most commonly, esports is regarded as a computer-mediated sport where people use technology to train and compete against others [41, 98]. There also seems to be a consensus for esports to be synonymous with competitive multiplayer gaming that involves spectating [42, 96]. Regardless of its definition, the nature of esports involves a rich ecosystem of both amateur and professional players who often play at home to refine their skills for intense competitions [42, 95]. Further, esports is considered to be a unique form of virtual gaming with an enthusiastic community that is passionate about esports games, players, and teams. In esports, competitions often center around team-based gameplay and interactions, which is one of the core research interests in CSCW [2].

In particular, the last decade saw a dramatic growth for esports with an increasing number of contests and events that captivated millions of enthusiasts both offline and online worldwide [6]. Gradually, with the modern amenities of technology, some esports now allow players to compete remotely while also allowing spectators to watch across the world. Thus, the ability for esports to be spectated live worldwide has made it a huge industry [45]. The growing popularity of esports all over the world and especially among the youth section of society has opened up new avenues of research for computer-mediated collaboration, virtual teamwork, and team-based social activities in CSCW [28]. In this paper, we see esports as a unique and valuable context to further extend existing CSCW literature on teams and teamwork from a cognitive perspective.

First, considering the collaborative nature of esports, esports offers a unique opportunity for researchers to investigate both team formation and team cognition. Though some indicate that esports lacks core physical activity elements and organizational structures to be considered a full fledged sport [40], others argue that esports should be considered a sport based on skill requirements, competitive nature, and potential physical exertion [51]. Regardless, teamwork has been acknowledged as one of the most important components to be successful in esports [94]. Teamwork for esports players happens virtually in an extremely competitive and pressured environment that demands quick decision making and frequent reflexive responses coupled with a few defined physical activities [30]. Further, esports is a combination of recreation, action, competition, and collaboration where teamwork is task specific [29]. An interesting component of teamwork in esports is the diversity to which teammates are familiar with one another. While some teams are composed of long-term teammates, other teams are composed of acquaintances or even strangers [30]. Therefore, the diverse virtual teams found in esports offer an interesting prospect for CSCW researchers to investigate team cognition from varying team composition perspectives.

Second, as esports teams are considered to be action-oriented, it is clear that the players involved must execute highly interdependent and time sensitive tasks in stressful environments [22]. For a game session, players need to strategize their game plan by making suitable connections with their fellow members. Furthermore, teammates must realize one another's strengths and weaknesses to gain mutual understanding. This understanding helps the team respond promptly to a situation that requires shared responsibilities. Since players often need to change their strategy mid-game quickly

and effectively [98], mutual understanding and common ground can produce a more coordinated team response. In short, esports teams create a unique platform to observe and understand how players perform at a team level in order to improve decision-making in a fast-paced environment.

Third, the utility and usefulness of coordination and communication in competition has been analyzed to emphasize their importance in esports [59, 66, 93, 100, 104]. In many cases it is observed that verbal communication is more effective [93]. One reason for this is the fostering of trust that can occur while using voice instead of text-based communication [100]. However, depending on the genre of the game, the type of interaction and collaboration might emphasize the use of non-verbal communication. In shared virtual spaces, these synchronous non-verbal cues can make or break the entire collaborative process during the game [59]. Thus, esports as a research platform offers an opportunity for the CSCW community to better understand how multiple modes of virtual communication can be used to express human traits and assist in the collaborative process.

With these being said, esports is creating opportunities for HCI and CSCW researchers to delve deep into team dynamics where players constantly need to exhibit their cognitive abilities in a dynamic environment [30]. This includes the fast processing of huge amounts of information produced every moment. Further, cognitive team abilities permeate the entire process. Cognitive load and player experience go hand in hand to bring about smooth coordination, accurate action, and team collaboration [7]. Though the teamwork requirements in esports are well understood [30, 94], a review of the literature has revealed very little understanding regarding the cognitive aspects of esports teamwork [55] and no research pertaining to team cognition in esports. Further, team cognition research can benefit from the esports research platform, which offers a better understanding of distributed teaming and collaboration in a fast-paced and dynamic context where teammates are often strangers. Therefore, to address these research gaps, in this paper we explore: 1) how team cognition is perceived and defined in an esports team context (RQ1); and 2) how team cognition emerges in esports (RQ2).

3 METHOD

3.1 Data Collection

3.1.1 Recruitment. To collect data, we conducted in-depth semi-structured interviews to understand how team cognition is perceived and how team cognition emerges in the context of esports. Recruitment messages were posted in Facebook esports groups, Reddit, and esports collegiate clubs. First, we utilized a keyword search method to find esports groups on Facebook. In addition to "esports club", "esports *University Name*" was also applied to keyword searches considering that many universities have their own esports collegiate groups with a great number of esports players. We then posted recruitment messages on those groups. Recruitment information was posted on Reddit at around the same time to recruit participants. In addition, we directly contacted esports players whom we already knew to invite them to participate by using a snowball sampling method.

3.1.2 Interviews. As a result, 20 interviews were conducted via discord, phone call, or face-to-face based upon participants' preferences. In each interview, up to 30 predefined questions were asked. Since questions often overlapped, had follow-up questions, or were answered by participants before the question was asked, 30 questions is an approximation. The first 10 of these questions were short, close-ended questions such as demographics, how long they had been engaged in esports, what esports games they usually played, etc. Then participants were asked about their collaboration experience in the context of esports (e.g., "When your team starts playing together to complete a task/play session, what did you think? Just your first thought?, How does your team overcome different ways of individual thinking in order to accomplish the task/play session?, How

Table 1. Demographic Information of Interviewees

ID	Gender	Age	Location	Occupation	Experience (Years)	Competitive Experience	Esports Games Usually Played
P1	Male	18	USA	Student	1	Amateur	LoL
P2	Male	22	USA	Student	6	Amateur	Dota 2
P3	Male	21	USA	Student	5-6	Amateur	LoL
P4	Male	30	USA	Student	11-12	Casual	FIFA; CS: GO
P5	Male	31	Canada	Software Engineer	10-11	Amateur	CoD
P6	Male	22	USA	Student	NA	Amateur	CS:GO; DOTA 2; FIFA; LoL; Starcraft
P7	Male	23	USA	Student	12	Amateur	DOTA 2; Apex Legends; Overwatch; Starcraft
P8	Male	19	USA	Student	1	Amateur	PUBG
P9	Male	30	USA	Biologist	18-20	Pro	DOTA 2; CoD; CS:GO; Fortnite; Apex Legends; Starcraft 2
P10	Male	22	USA	Student	10	Casual	LoL; CS:GO
P11	Male	22	USA	Student	3	Amateur	LoL; RB6S
P12	Male	23	USA	Student	10-12	Amateur	Hearthstone; Dota 2
P13	Male	25	USA	In between jobs	12	Casual	Apex Legends; CoD; Fortnite; Overwatch
P14	Male	25	USA	Healthcare employee	13	Amateur	CoD
P15	Male	24	USA	Artist	3	Amateur	RB6S; CS:GO
P16	Male	25	Canada	Clinical Researcher	21	Amateur	LoL; CoD
P17	Male	22	USA	Student	10-12	Amateur	War Thunder; Overwatch; Rocket League; RB6S; World of Tanks
P18	Male	23	USA	Software Engineer	4	Amateur	LoL; CS:GO; Overwatch
P19	Male	24	USA	Student	7-8	Casual	LoL
P20	Male	30	USA	Student	7-8	Amateur	CS:GO; CoD; FIFA

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

does your team determine what was important or not?"). The last part of our interview was related to (1) the development of team cognition during gameplay (e.g., *"What do you feel led to having/ or not having team cognition?"*, *"What technologies, tools, and/or mechanisms do you feel help build team cognition for your team?"*); (2) factors that may impact the emergence of team cognition (e.g., *"How does your team develop a shared understanding of the task and team?"*, *"How do you think about approaching collaborating with your team initially?"*, *"Does a leader emerge in your teams? If so, does that help or hurt the development of the team cognition of your team?"*, *"Do you feel your previous experience of teamwork helps you to better develop team cognition in your teams?"*). The following definition of team cognition was provided to participants beforehand: "Team cognition is the ability to process information and share information at a team level, as opposed to just individually. This is also known as common ground or being on the same page as other team members."

The average length of the interviews was around 30 minutes. The average age of the participants was 24 years old, and the average experience within esports was around 9 years. Table 1 presents details about our participants. Notably, all of our participants were male. Though this severely limits the generalization of the findings for this study (which is further discussed in the Limitations section), this participant population unfortunately reflects the lack of diversity in competitive esports. A recent survey of collegiate esports teams revealed that males made up 89% of the population [1]. Similarly, in the most popular esports genres such as *Multiplayer Online Battle Arena* and *First-Person Shooters*, females make up 10% and 7% of the population respectively [105]. Though we did not actively recruit males, the self-selected participation population is evidence of the poor female representation in esports.

3.2 Data Analysis

We used qualitative analysis based on the grounded theory [34] to generate an in-depth investigation of how team cognition is perceived and developed in an esports context. All interview

Fig. 1. Refining of Themes

Phase	RQ1 Themes		RQ2 Themes					
2	Understand preferred strategies & reactions 16	Understand strengths/tendencies 17	Sharing/Pushing information 12	Shared experience in-game 18	After game review (discussion) 10	Discord or voice 18	Accommodating other playstyles 8	Removing toxicity 8
	Defined roles 15	Trust 4	Adaptability 8	Experience in team games 14	Planning/strategy 14	Pinging 6	Allow disagreement & suggestions 9	Selflessness 6
	Understanding role interdependency 4			Developing team chemistry 8		Communicating quickly w/ leadership 17		
3	Shared awareness of dynamic game flow	Understanding of skills and personality	Sharing behavior in actual gameplay	Experience	Preparing for games	Communicating quickly and precisely	Creating Social Atmosphere	
5	Shared awareness of dynamic game flow	Mutual understanding of skills and personality	Sharing behavior in actual gameplay	Growing experience of interpersonal connections and game mechanics	Preparing for background knowledge and gameplay strategies	Communicating quickly and precisely	Creating a social atmosphere to resist toxic behavior	

data was analyzed using the following steps/phases: (1) three of the authors read through all the participants’ narratives to acquire a basic understanding of how team cognition, including the shared understanding of tasks and teammates, was developed in the overall collaboration process; (2) three of the authors identified thematic topics based on participants’ description of their team collaboration experience in the esports context for further analysis; (3) all authors discussed and refined themes and sub-themes in a collaborative process to ensure the developing process of team cognition reflected by the collected data was fully understood; (4) the first author extracted quotes based on themes and sub-themes identified in the third step; (5) all authors further discussed and refined themes and sub-themes and used the quotes to generate a synthesized description of how team cognition is perceived and developed in an esports context.

Figure 1 outlines the refining of themes throughout this process. As mentioned, Phase 1 resulted in three authors having a basic understanding of general themes present from reading all 20 transcripts. In Phase 2, these same three authors independently re-read each transcript and categorized participant answers or segments of answers into themes that they identified. Some of these categories were identified by authors before re-reading and some of these categories were added as certain quotes required new categories. This was largely accomplished through the use of independent spreadsheets for each author, copying responses into cells with columns matching themes and rows matching participant ID, and the use of color coding and highlighting when necessary to indicate potential new emerging themes. Though there were differences in what themes/categories resulted for each author, much of these differences pertained to the wording used to describe each theme. With similar themes consolidated and unique themes added, Figure 1, Phase 2 shows all the themes identified during this phase. Phase 3 involved all authors looking at the quotes for each category and collaboratively refining the themes into major themes for each research question. RQ1 themes are shown on the left while RQ2 themes are shown on the right of Figure 1. Additionally, counts of participants who mentioned each theme were created during Phase 3 to better inform the thematic analysis process. These counts are shown in the bottom right corner of each theme in Phase 2 of Figure 1. The resulting themes of the collaborative and iterative conversations during Phase 3 are shown in Figure 1. After the first author extracted a collection of useful and descriptive quotes for each theme in Phase 4, all authors reconvened for additional discussions to ensure that the quotes and theme categories best represented one another. The resulting themes are shown in Phase 5 of Figure 1.

4 FINDINGS

In this section we present our findings regarding how esports players perceived and defined team cognition (RQ1). Additionally, we outline strategies that esports players used to facilitate the emergence of team cognition in an esports team context (RQ2).

4.1 Perception of Team Cognition in Esports

Though team cognition is perceived and defined in many ways by esports players, we found three major themes that were commonly discussed and emphasized by most participants: 1) shared awareness of dynamic game flow, 2) mutual understanding of skills and personality, and 3) sharing behavior in actual gameplay.

4.1.1 Shared awareness of dynamic game flow. Many esports players understood and experienced team cognition as a shared awareness of dynamic game flow in their gameplay process. A unique aspect of esports that separates it from most sports and other team contexts is the dynamic nature of the competition. Teams must rapidly adapt and evolve their strategy in-game due to a multitude of changing factors (e.g., game environment, character skills and powers, opposing team strategies). Further, the underlying game itself changes frequently as developers change the "meta" of the game in terms of new heroes and weapons or balancing of old game aspects [64]. The challenge of having shared awareness in esports was highlighted by P1 (male, age 18):

I think we think differently because the game is not constant. So like what I mean by that is no game [is] the same every single time we start up again. So that leads to different creative minds and different creative approaches. (P1)

Here P1, who plays the ever-changing esports of *League of Legends*, noted how challenging it can be for teammates to be on the same page. However, most participants emphasized the importance of being on the same page with their teammates as it allows them to react to situations quickly with minimal communication. Reacting quickly is especially important in esports due to the fast-paced nature of the competition. At its most basic level, shared awareness for esports players requires them to understand core game mechanics and how to react to the game itself. This basic awareness was described in the following:

Usually everyone kind of knew what the decision was before we started discussing it, like when the safe zone would change, everybody kind of knew, you know, you head to the center. And so it wasn't like people were bringing all these brand new ideas to the table every time unless it was a really unique problem that we came across. Generally everybody was kind of on the same page. (P8, male, age 19)

P8 highlighted a standard game strategy in the game *PUBG*, moving to the safe zone, that is likely shared among any player that has experience with the game. Thus, this awareness is transferable to new teams even if the players do not have experience with one another. Other participants mentioned shared awareness that involved a more advanced understanding of the dynamic game. An example of such awareness includes the following quote:

Okay, so if I usually play in the mid-lane and so if I move up to help top lane generally I don't need someone to come help in the mid-lane just because it's a short trip. But usually without talking we're really good at rotating people to someone else to mid lane someone else to jungle and me the top if we need it... But when people do need to come we've gotten to the point where we don't need to say it. They just kind of know. (P19, male, age 24)

P19 mentioned covering lanes for teammates when they move. This strategy or technique is likely understood by most experienced *League of Legends* players, though the level of communication required likely varies based on the team's experience with one another. As teams gain more

experience with one another, the communication required to coordinate lessens, an important aspect and benefit of common ground [14, 67]. This was articulated by P10 (male, age 22):

Just kind of set in at a certain point at a certain critical mass of games play, you start to know what your companion or your teammate is already gonna do. So you can just ping it and say I'm commit and he goes, yep. And you already know what the play is going to be because you've done it so many times. And so you know, how he's gonna react, you know how he's going to engage the play, or the you know, a certain mechanic, you know, how he's gonna start it, you know, he's gonna act and he knows, or you know, that he knows what you're going to do. (P10)

P10 mentioned reactions that rely more on an understanding of the team's underlying strategy and an understanding of a specific teammate. Understanding of teammates will be further discussed in following sections. In the quotes above from P8, P19, and P10 it is clear that players were able to draw from previous experience and knowledge of the game to coordinate their actions. They knew that certain behaviors on their part would be predictable by their teammates which lessens the requirements for communication. Further, players were able to act in ways based on how they predict their teammates will react.

As seen in the quotes above, shared awareness can be realized by teams at different levels. Regardless of the degree to which teams participated in shared awareness, participants consistently emphasized how important shared awareness was in general. The following quotes give examples of the perceived importance of shared awareness by participants:

So there are some teammates that are really quiet and I don't like playing with. Because ... then you end up jumping into [situations] without a proper strategy and then you end up messing up the whole fight right? I prefer people who will like we'll discuss the strategy and discuss actions and stuff in that culture communication is important (P2, male, age 22)

You might have a player that has a completely different playstyle and attitude towards the game of how it should be played than the other four. [And if] that's the case, there might be a precedent set in order to find a more applicable member. (P10, male, age 22)

P2 understood that communication and shared awareness were critical to the success of the team. For P10, the value of shared awareness was so important that the team would consider removing a teammate if being on the same page seemed unobtainable. These quotes indicate that having shared awareness of the game with teammates not only helps with team performance, but also improves the enjoyability of the game.

4.1.2 Mutual understanding of skills and personality. For many esports players, team cognition is perceived to be better in teams where teammates understand one another. They considered that team cognition should include both mutual understanding of teammate skills and personalities. If teammates understand the skills of one another and how specific teammates will react to certain situations, esports players can better adapt and coordinate in the face of a fast-paced competition. For instance, players can account for different personalities and tendencies when formulating a plan or adapting to situations. P16 articulated this accounting and its benefit:

Some individuals want to win according to their own objectives, like they want to have the most kills in the game, or they want to have the best k-d ratio, versus actually playing to the team focused objective of the game. And that can definitely impact the performance of the team. However, I've definitely noticed that as long as it's accounted for, the team can usually work around it. So if someone is more of an upfront type of person, and they

want to really just get into the action and go at other people; as long as we account for that in a plan, it seems to work out better. (P16, male, age 25)

For P16, he perceived that the negative impacts of a teammate's selfish tendencies in the game *Call of Duty* can be mitigated or completely erased if the team acknowledges and accounts for them. Without accounting for this behavior, the selfish teammate is likely perceived only as a liability and not as an asset. P19 similarly described how their team accounts for varying playstyles:

Yeah shared understanding of what we're good at, and also just our playstyles. So there's times where I will just quickly make the decision to go roam to the top. My friends know when I'll do that, so if they're in a position to help - they'll react and help without me even saying anything. (P19, male, age 24)

P19 indicated that his teammates can respond to his behavior in certain situations without communication because they are accustomed to his playstyle. This understanding frees P19 to play in a way that they personally enjoy while also allowing the team to predict and account for this deviance. As esports involves communicating a lot of information, reducing the communication requirements can be useful to streamline information sharing. Though understanding a teammate's tendencies and personality are important in esports, knowing a teammate's skills and knowledge are also important in developing a plan. Examples of understanding a teammate's skills include the following:

Certain people have certain qualities that everybody knows about. So some people are always good with shortcuts. So they should always be in the field. (P20, male, age 30)

Do we know our teammates? That comes from just the experience of playing games with them and understanding what they're good at, what situations they're not good at, when they're strong when they're not, and just how that kind of can be facilitated into the grander strategy. (P10, male, age 22)

Both P20 and P10 mentioned their awareness of their teammates and what they are good at based on their experience with them. Using this understanding, the team can then create a better and more personalized strategy that will play off of the strengths of their team. This is a benefit that experienced teams have over less experienced teams as seen in the following:

If you can get a full lobby of everyone you know, then they're going to be on the same page. But if you get like someone newer you know, it's kind of tough because then not only need to learn how that person's playstyle is - do you need to protect them or you know, protect yourselves you can do that. And so like when you have that it's all about communication. Because if you know, you're weak at something you know, or you know, someone's weak at something everyone needs to know, so they know how to protect each other and protect that person to help you succeed. (P14, male 25)

An interesting aspect of P14's quote is the distinction for new people joining the team. When there are new people introduced to the team, P14 noted that it is challenging to account for their actions or strengths. Without this teammate understanding, more monitoring or communication must take place in order to know what a teammate is doing or going to do.

In certain team contexts, a critical threshold of mutual understanding can result in trust. As teammates play with each other more and gain mutual understanding, trust develops as an emergent property. Trust was emphasized as a key component of team cognition and teammate understanding by several participants. An example includes the following:

I believe through this team or through us playing together for pretty much only like less than a month we have gains a lot more coordination because we're trusting each other. And I think all of us are just a lot more excited to improve. (P1, male, age 18)

For P1 there seemed to be a positive feedback loop that starts with experience. This is similar to how risk-taking behaviors like disclosure, reliance, and contact-seeking can increase trust within a team [11]. As the team gains experience they understand one another more. As teams understand one another, they are able to predict each other's actions which increases trust and improves coordination. This increased coordination is notably exciting which encourages the team to practice more and gain more experience. P11 (male, age 22) also discussed the importance of trust:

There's a lot of trust that goes into it. So it's more getting to know your team and knowing you have to put trust into them... So you have to kind of know or trust that they're going to be able to do the tasks that they're supposed to do. There's always a chance they won't be able to sometimes and you kind of have to know and be prepared for it. (P11)

Important to P11 was being able to "trust that they're going to be able to do the tasks." This sentiment is in line with prior research which has revealed that virtual teams are more likely to rely on cognitive trust than affective trust [50]. Once teams establish this trust and understanding, players can focus more on their individual task which will contribute to the team's overall strategy. Further, players can tailor their individual tasks to complement the actions or expected actions of teammates in order to gain an overall increase in performance.

4.1.3 Sharing behavior in actual gameplay. Based on their shared awareness of dynamic game flow and mutual understanding, esports players develop an understanding of what to share and whom to share it with. This sharing behavior emerged as one of the three major themes for how team cognition is perceived in the esports team context. As mentioned previously, it is highly important for esports players to be able to communicate information quickly and precisely in the fast-paced esports environment. Because of the amount of communication and stress during competitions, it is important to limit the communication to what is necessary and indicate who the information is intended for so as to not distract players from their current task. Having a shared awareness of the game and a mutual understanding of teammates informs this communication. The importance of this communication was mentioned in the following quote:

Having the ability to feed your team information is really, really beneficial because someone might not know [what someone else does]. So that's why it's up to other team members to feed that information because no one is going to look all around the map all the time. (P1, male, age 18)

A common feature of esports is players having incomplete information. This feature makes esports both challenging and interesting as players must rely on one another to perform effectively as a team. P1 highlighted this necessity to share information in his awareness that some team members will have information that other team members require. This sharing practice lessens the requirement for players to seek out information outside of their area of responsibility knowing that their teammates can provide them with information. In addition to communication and coordination affecting team performance [52], this sharing behavior reduces the cognitive load of each team member. P10 (male, age 22) described another sharing behavior that reduces cognitive load:

Being able to swiftly boil down what you see and deliver to the team so that they can understand it. That was something that was... refined through experience playing with those particular people. You'll know that - he doesn't need to know that because it doesn't concern him. He doesn't need to worry about it. And then hey, if it's something that's going to affect the whole team, okay, beautiful. Let me dictate that, "this is something that's coming up, be ready."

P10 emphasized two important components of effective information sharing with esports teammates. First, the communication needs to be quick and concise. Since the map is changing quickly

in the dynamic game environment, if communication takes too long, the information might be irrelevant or inaccurate by the time the teammate receives it. Further, communication must be concise so that team members can return their attention to their task or so they can receive further communication. Secondly, P10 mentioned the importance of sharing the correct information to those who need it. This refined sharing behavior is an important component of team cognition for esports as it reduces the cognitive load of team members who do not need the information. Further, this sharing behavior is more pronounced in esports compared to traditional sports that might not offer the communication affordances of esports.

4.2 Facilitating Team Cognition in Esports

Though RQ1 answers the question "How is team cognition perceived in esports?", RQ2 looks deeper in asking "How does team cognition emerge in an esports team context?". Major themes such as experience, preparation, communication, and atmosphere were identified for facilitating the emergence of team cognition in an esports context.

4.2.1 Growing experience of interpersonal connections and game mechanics. Unsurprisingly experience, which came in many forms, was identified as one of the major facilitators for team cognition in esports. Helpful experiences included experience with teammates in the same game, experience with teammates outside of the game, experience with teamwork, and even simply experience with the game's mechanics. The following are a small sample of the many instances where participants expressed how experience with teammates in the same game proved beneficial in developing team cognition:

So I know from personal experience that over time [we] will develop that understanding with each other. Because I've seen it with numerous teams that I have worked with. I mean, you figure you're working with these guys, I will say 10/20 hours a week, for the game, right? You're gonna pick up on how each person wants to approach the situation and stuff like that. (P3, male, age 21)

I mean, that's just experience. That's just us. Not only being in a lot of games and understanding how different roles are supposed to be played, but just games with each other, you know, you just can use people's [playing] style and understand where they're going to be. Where you need to be. (P13, male, age 25)

These two quotes described how experience with teammates in the game supported the emergence of team cognition. The more team members played with one another, the more they were able to predict how their teammates would perform and respond in certain situations. Though most players expressed a similar emphasis on experience with players in the game, some players expanded on this to note the importance of experience with teammates outside of games:

I think what led to having the team cognition was getting to know each other better outside of the game. Just while we know our individual skills, you're only looking at your own screen. You only know what you're going to do. And so until you know the person, the other people, behind the screens, it's hard to know, on a team level, how they're going to work. (P8, male, age 19)

Meeting in person really helped just to get kind of a general vibe if that makes any sense of them, of who they are. So that kind of made me more comfortable with the people themselves. (P10, male, age 22)

Though getting to know teammates outside of esports gaming is not a requirement for team cognition, certain participants noted that it can be helpful. These participants perceived offline experience as a method to facilitate getting to know one another on a deeper, more personal level.

They also considered this deeper knowledge of teammates as another factor that helps them predict their teammates' actions and behaviors online. This benefit of interacting with esports teammates offline adds to prior research indicating the benefits of social support that esports players receive offline [30].

In addition to experience with teammates, general team experience was perceived to be transferable as well. Players expressed how their experience with other games, sometimes not even esports games, helps them develop team cognition with new teams. Examples of this are seen in the following quotes:

Growing up, not only do you play a lot of esports but you play a lot of sports. But everything you learn is communication. Everything you learn is being able to see a problem and address that problem, and not just like go... So the more you see it the easier it is to speak up as a new team. (P14, male, age 25)

According to P14, teamwork at its core is highly transferable. Thus, even experience in offline sports help players develop problem solving and communication skills that can be used in various contexts. Other transferable coordination skills were mentioned by P7 (male, age 23):

I think learning to coordinate with a whole bunch of different kinds of people, sharing between language barriers and personality disputes, and kind of getting past that enabled me to understand team cognition. (P7)

Here P7 discussed the importance of experience working with diverse teammates. As teams likely contain members with diverse personalities and cultures, the ability to work with diverse teams is important and transferable to new team settings. Though a previously studied challenge of virtually teaming with strangers is the higher effort required to maintain a positive collaborative atmosphere [56], P7 perceived that repeatedly teaming in these diverse environments has trained him to coordinate better overall. Another participant also described how experience with different teams can help with new team formation:

So the more teams you play, the more you kind of know how different players are, how they think and what they tend to do in certain situations. And I think that helps in the newer teams where, a similar situation comes in and, now we know what's gonna happen beforehand and even, just warn them or advise them against it, and stuff like that. (P6, male, age 22)

Though every teammate is unique, P6 perceived that there are certain patterns or tendencies that are recognizable in players. As you play with more and more teammates, recognizing teammate patterns can assist with team cognition. This teammate pattern recognition was also described in the following quote:

Yes, [experience] definitely helps me identify patterns of behaviors that people will engage in such as - someone that's typically more wanting to be up in the action and up front and always kind of constantly go go going. Those individuals would definitely be more likely to reject a plan or scenario in which we're trying to be really stealthy and slow... And so after those prior experiences, you can share them on to the future kind of games because, though the like content in the game itself changes, the mechanics of the games themselves don't really change all that much. And so that's how you're able to kind of build off personal kind of team dynamics in order to kind of assess how you would interact with future games or future situations. (P16, male, age 25)

Similar to P6, P16 emphasized the importance of experience recognizing teammate behavior that can be useful in facilitating team cognition. Additionally, P16 described how general game experience can support team cognition due to the similarities between games. Since esports are

typically team oriented, understanding team dynamics in one esports game is transferable to other esports games.

For the participants in the four quotes above, players perceived certain components of teamwork and communication as common and transferable from their previous experience with other games. Thus, they perceived team cognition emerging faster with new teams as they were able to transfer their previous experiences to a new context. This transference is even more pronounced if the teamwork experience is within the same game. Participants often mentioned how their knowledge of a specific game's mechanics helps them develop team cognition:

Oftentimes it's experience and just knowing the game's mechanics. Because in those games, there are specific roles that are very specific to like, what they're supposed to be doing. I think people end up understanding [this] intrinsically, the more they play. (P7, male, age 23)

So typically, in a lot of these games, it's based on pre built character selections. So you can kind of identify what the moves of a character would be. This is obviously more towards League of Legends. With the moves of the champion would be kind of based on what you already know about them. So we can already identify, oh, this type of character would be more in the back trying to pick us off with long range high damage attack, so we should probably focus them if we can get past the front line tank. (P16, male, age 25)

For many team-based games, such as *League of Legends* mentioned by P16, game designers design for the mediation of team cognition. Characters in these team games are often designed to have certain team roles that interact with other characters in specific ways. In this way, as players gain experience with the game's mechanics, players are able to form team cognition with new teammates more quickly as they are able to predict how other players will react to certain situations based on their selected character. In summary, though experience with both the specific game and the specific teammates are ideal for the emergence of team cognition, other experiences can be highly relevant in supporting team cognition in the esports context.

4.2.2 Preparing for background knowledge and gameplay strategies. For experienced teams, taking time outside of gameplay to ensure that everyone is on the same page is a key component in facilitating team cognition. Though players often assume that everyone thinks about the game and associated strategies the same way they do, going through the process of discussing game strategy often reveals the need to articulate different visions. P14 (male, age 25) discussed the importance of strategy:

I think most people who take gaming kind of seriously - they understand that competitive, it's not a reactionary thing you're trying to do meaning if something comes at you, you're not trying to react to it, you're trying to plan for it. You have to understand what to do when you get to that point. Reactionary you often catch yourself struggling because you just can't react sometimes. Sometimes you have to. But if you can plan and prepare and get everything set everything goes much more smoothly. (P14)

As indicated by P14, there are certain pitfalls to reactionary behaviors in esports. Since esports is so fast-paced, it is important for teams to react appropriately, quickly, and of the same mindset when things happen. Discussing situations outside of games enables teams to prepare for situations and gives them confidence that their teammates will react in a similar way. One of the popular ways that competitive esports teams plan is by using replays or reviews of previous games in order to better prepare for future competitions as described in the following:

And then after say a scrim [or the] matches for the day, then when we go back and review the boards. We can go back and say okay, did we improve on this thing that we set out to

improve on - what we stated that we would try to do better in the beginning. (P10, male, age 22)

P10 described this review process in the context of goal setting. Comparing their performance after the game to goals they set assists the team in getting on the same page with what they think is important, what areas they want to improve in, and how successful they perceived themselves to be in meeting these goals. P3 (male, age 21) expressed a similar experience with replays:

I think one of the things that I like to utilize when trying to do that is going over with the replays where you might even have access to the players were saying, and sort of going through those moments with each other. Just because it helps everybody to realize like what's really happening in the moment. (P3)

Preparing is a key component for competitive teams in that it facilitates important conversations that help teams better understand the game, their teammates, and how they should react to situations as a team. As mentioned by P3, there is often a disconnect as individuals are seeing and experiencing different aspects or viewpoints of the game. Going through certain moments together helps each individual gain a more complete picture of what is happening outside of their own stressful in-game environment. As team members gain a more complete picture, they are able to perform better in the future by better predicting what specific team members mean by certain call-outs or by knowing how teammates might react to specific situations.

4.2.3 Communicating quickly and precisely. As alluded to several times in this paper, one of the distinguishing characteristics for most esports games is the fast-paced nature of competition. Because of this, sharing information and communicating it quickly in-game is an important component that is necessary to mediate the emergence of team cognition. Several participants emphasized the importance of the communication being quick including the following two quotes:

The core is communication to be able to do anything in any of these games. And the better you can communicate with others - the better you can quickly interpret what you're seeing into the verbal announcements, including your own statuses and also filtering out the ones that are pretty nonsense or not important. (P9, male, age 30)

I think that the best way to communicate is it's all about being short and precise with what's happening... So if you can get communicate quickly and precisely then someone can get over there and either help you or come up with a strategy next time to help you or be there. (P14, male, age 25)

For P9 and P14, quick communication was a skill that each member of the team should become proficient at so that information is shared quickly and effectively. However, some participants noted that a leader or "shot caller" was vital if communication is to happen quickly:

I think [leadership] helps because... when the person who is generally called a leader (who is the best strategist or whatever) makes a decision, nobody's going to question it. If the group respects him as a leader, and if you can get a team to not question like some kind of behavior, it's very good because you get everyone on board at the same plan at the same time. It's like "a good plan executed now is better than, you know, a great plan executed too late". (P17, male, age 22)

For P17, leadership was perceived as the best way to communicate quickly. If there is a strong leader on the team, each team member will respond to commands quickly which can increase in the effectiveness of the executed plan. What is mentioned in all of these quotes is the importance of quick communication. Though players mentioned different methods for communicating quickly, most discussed the importance of using a microphone instead of typing to communicate information.

Often players mentioned Discord, a software outside of the game environment that players use during games to communicate using a microphone:

So we basically whenever I played DOTA I'm always on Discord with my teammates, right? So we are constantly discussing and talking like what do we do now? What do we do now? (P2, male, age 22)

While most players mentioned Discord or similar voice apps, others discussed the importance of visual communication. Many games offer the ability to place visual markers that teammates can see as a way to quickly communicate objectives, enemy locations, events, etc. The importance of these visual communication markers in online multiplayer game teamwork has been described several times in prior research [8, 59, 103, 104]. P4 (male, age 30) discussed how this visual communication can supplement voice communication:

You can shift click something you will be pinging on location. So you're pretty much drawing attention to that spot. And your other teammates would know like "hey, you have to look there in the map to see what's going on." It's not just verbal communication. (P4)

This pinging communication has some notable benefits in esports. As P4 mentioned, this form of communication is quick as it only requires players to click on a location. Secondly, this communication reduces the amount of auditory information teammates are receiving (i.e., a quick sound effect and visual indicator rather than a verbal explanation) which can distract them from other verbal communication or important sound cues in game. Finally, pinging has the added benefit of providing spatial information as the ping is often associated with a specific location on the map.

Though most esports teams can communicate with decent effectiveness using voice and pinging, exceptional and quick communication is developed through shared experiences in-game. As teammates play more and more games together, they develop a shared language that can be used to communicate both more quickly and effectively. The following quote shows what this can look like:

Because if I know map awareness, I can say, hey, look, there's this type of player, at this specific location. And if I say that then everybody knows exactly what I'm talking about. But if you don't know the map, then you don't really know. Yeah, having a general understanding, having the same kind of communication when you're aware of what I'm talking about and exactly how to help...It's all about being concise and to the point in getting your point across. (P14, male, age 25)

P14, who was discussing his experience with the game *Call of Duty*, noted the importance of teammates having experience with a game and specific maps. As players gain experience with a map, they can better communicate spatial information that is relevant to their teammates. This type of shared language is transferable to different teams as long as the other teams have experience with the map. However, more accurate forms of shared language are specific to experiences with specific teammates:

So right now, it's been a lot of, "there's a guy by this fire hydrant in the intersection." And we're just hoping that the rest of the team can identify it. But over time it starts to go we can try and do landmarks or locations that we're all recognizing. (P16, male, age 25)

P16 described the struggle their team currently has with a new map. Since they have not had many shared experiences on this map, their language for communicating information is perceived as weak. Over time P16 expected that their shared language would improve with more map experience. One way of developing shared language is by having a common leader:

A lot of times, that leader is the one who helps you develop the lingo and understand the map and helps you problem solve through everything. So if you all learn from one person

and you're on the same, you know, mindset of what to do and certain things like that.
(P14, male, age 25)

In this quote, P14 highlighted how a common leader can help a team develop a common lingo. When teams develop this common language, they are able to push information that their teammates need more concisely. Further, teams are able to react and make decisions faster with more precise and concise communication.

4.2.4 Creating a social atmosphere to resist toxic team behaviors. It is well established that online competitive environments have a tendency to be negative and toxic [3, 58]. Interestingly, participants from this study discussed their aversion to toxic team environments as an important mechanism to facilitate team cognition. An example of this sentiment includes the following quote:

Generally my thoughts - first is how is everyone's like personalities going to mesh in, at least decently? Well, because I'm not a huge fan of toxic team environments. That's my first thoughts. (P18, male, age 23)

Further, participants were often cognizant of how team environments can negatively affect the emergence of team cognition. The following participant discussed their dislike for toxic teammates and their affinity for healthy communication:

There's the emotional side - there's people that get angry really quickly and they're not going to communicate or take communication. For emotions, the people that are relatively stable, grounded people - they're easy to communicate with because they're paying attention and they're not stuck in their own head. (P19, male, age 24)

As discussed previously, communication is perceived by esports players to be important in supporting team cognition. For P19, emotional or unstable people are perceived to inhibit communication and thus team cognition. In addition to their dislike for toxic teammates, players also discussed the importance of healthy environments and teammates being willing to learn and adapt:

Just making sure everyone is willing to learn. Make sure everyone's willing to adapt. Adaptability - I would say it's probably another very big, big trait that would help encompass team cognition better for the team. (P18, male, age 23)

This adaptability of players often manifests in their ability to realize other players' playstyles and a willingness to accommodate such differences. The following participant mentioned the importance of this accommodation and the potential issues when this adaptation is missing:

So, you know, whatever playstyle your teammates prefer you want to work with them. Because if you're in a role that you don't fulfill, well, then you're going to have bad chemistry. (P15, male, age 24)

For P15, "bad chemistry" could have a negative affect on team cognition as it increases the likelihood of selfish behaviors. Thus it is important for teams to make sure that each team member is in a role that they enjoy filling. The following quote discussed this notion further:

We want to kind of be cognizant and considerate of our personal playstyles because that's part of the game - is having fun. It's not just about constantly winning. So in order to respect that playstyle but still obtain the objective, we plan in those certain attitudes... We start to recognize our abilities, our playstyles, and then we become more aware of the map and we start to kind of hybridize those and our game plans become much more streamlined. (P16, male, age 25)

P16 discussed how important it is for everyone to be having fun. Teammates may feel disenfranchised if they are not having fun or feel like their skills are not being utilized optimally by the team. Having fun might seem trivial in a highly competitive environment; however, team members

having fun can help manage the stress associated with the competition and can lead to a more positive team environment.

Open communication has also been identified as crucial to facilitate team cognition in esports. P15 (male, age 24) explained some of the benefits of open communication:

Some people have their own ideas of how they want to do things - which is great, you know, the more people that are thinking about how to go or how to do certain things, it just expands your playstyle. You want to hear more creative ideas about how to go about things.

P15 importantly noted that each team member has different viewpoints based on different experiences of information they are receiving in the moment. P15 perceived this flow of ideas and perspectives as a positive for the team which can happen in the right team environment. This insight is similar to prior work which highlighted that collaborating with strangers in online games can lead to learning opportunities [73]. Another quote detailed a similar perspective:

So what will end up happening is that they'll be able, like I try to put it in place, an area where everybody can openly communicate with one another. And so one of the patterns of what we have for that open forum where people can disagree with each other, and be vocal about it, and then it sort of has that back and forth on you know, these different viewpoints and such. (P3, male, age 21)

Both P3 and P15 discussed how important it is for everyone to have a voice. In each of their descriptions, the open communication allowed the team to grow and develop from the various perspectives of the team members. Alternatively, P7 (male, age 23) mentioned how the opposite can happen:

Oftentimes, there's discussion. Sometimes in the less coordinated teams some people give up. They give up trying to push their own ideas. (P7)

For these teams, certain team members might become frustrated from toxicity or their ideas being suppressed or not listened to. The obvious outcome from this is certain teammates disengaging. This disengagement is damaging from a communication standpoint in that the team will lose an information source. Further, the team is losing a unique strategic perspective that might benefit the team's overall strategy formation. These interviews provide an interesting perspective on esports. Though toxicity is fairly pervasive in this community, most of those interviewed realized and articulated the affects that the team environment has on team formation and team cognition.

5 DISCUSSION

To answer our research questions, we have highlighted how players perceive and define team cognition in an esports team context (RQ1). Esports players define team cognition as a means to more effectively carry out cooperative tasks by being able to respond to the actions and responses of teammates. There are similarities between this definition and the definition provided to participants at the beginning of the interviews: "Team cognition is the ability to process information and share information at a team level, as opposed to just individually. This is also known as common ground or being on the same page as other team members". However for esports players, team cognition specifically takes the form of a shared awareness of the dynamic game flow, a mutual understanding of their teammates' skills and personalities, and their information sharing behaviors in-game.

In addition, we have presented mechanisms, processes, and strategies that support the emergence of team cognition in esports (RQ2). We found that players primarily rely on experience to support team cognition, though this experience comes from an array of contexts. Further, esports teams use

preparation techniques, communication strategies, and a positive social atmosphere to facilitate the emergence of team cognition.

As the popularity of esports continues to rise [6], its importance as a research platform will continue to increase [28]. The CSCW community shows great interest in how collaboration and communication can be better realized in computing contexts. A better understanding of teamwork in the context of esports will likely have useful implications for other online teamwork environments including the remote workforce. In this section, we discuss how our findings compliment and augment well established theories of team cognition and contribute to existing CSCW literature on computer-mediated teamwork.

5.1 Allowing Diverse Experiences to Support Team Cognition in Esports

Broadly speaking, the main contribution of this esports team cognition research is a better understanding of how computer-supported group work can transform into teamwork with new teams under time constraints. Though many attempts have been made to encourage teamwork within CSCW interfaces [63], much can be learned from the esports community. In esports, the team cognition occurs in a fast-paced environment where individual skills often cannot compensate for teamwork deficiencies. Further, many of the esports players interviewed offered descriptions of playing with new or random teams without prior experience with one another. These are important teams to study since it is known that collaborating with strangers requires extra effort to maintain a collaborative atmosphere [56]. One way in which esports players are able to develop team cognition quickly in both experienced and ad hoc teams is by utilizing diverse experiences.

First, our findings support a large body of work that indicates experience within the task is important for teamwork. Previous CSCW research has identified this task experience as a key component in team formation [27, 57] even within the specific esports context [30, 55]. From a team cognition standpoint, this is expected as team cognition is often tied to context [19, 26, 85]. Further, experienced teams take part in team cognition faster [17]. For these reasons, it is expected that experience with specific teammates in a specific game or context should support the emergence of team cognition. These experienced teams are known to "provide information to and request information from the right team member at the right time" [17].

Second, we offer additional evidence for how teammates can transfer their experience with known teammates to new games/contexts to support team cognition. Prior research has shown that the experience and success that teammates have had previously with one another can support trust [50] which in turn impacts future performance [24]. Though this trust was described by participants, other experience and team cognition connections are evident. As indicated by some previous research, experience with teammates is a facilitator for team cognition in that teams are able to transfer teamwork skills and inter-team interactions to a new task [18]. Our findings support this transference of experience to new contexts as players were able to use their understanding of teammate skills, personalities, and temperaments to be able to predict outcomes and coordinate within new games. However, our research focuses on, and thus extends these findings to the context of esports, multiplayer online gaming, and dynamic fast-paced virtual environments.

Third, our findings indicate that team cognition can be supported and quickly developed in new or random esports teams wherein team members have no prior experience playing with one another. This is of particular interest to the CSCW community as better understanding this impromptu collaborative dynamic can better assist in team formation for ad hoc distributed teams. Previous research has compared mixed teams (same roles on the team with different members) with intact teams and found that intact teams outperformed mixed teams; however, mixed teams exhibited higher levels of situation awareness and more flexible coordination [35]. Similar to how developers include ways for players to make awareness cues [103], our findings suggest that game developers

for esports games purposefully design other game mechanics with teamwork in mind. An example of this is esports games such as *Dota 2* and *League of Legends* and their implementation of roles. Players start each game by deciding which character they are playing as. These characters often have specific roles that might indicate how the character will interact with other team members. Role identification behaviors has previously been established as a core building block for team cognition [75]. This early role identification in esports supports team cognition for team members unfamiliar with each other who might otherwise require several games to perceive team cognition. Developing shared understanding early is especially important since global diversity, which often occurs in matchmaking, can negatively affect trust and thus team performance [32]. Thus, team cognition in these games can be supported by players' experience with the game itself rather than experience with each other.

5.2 Quick Decision Making and the Need for Shared Mental Models

The fast-paced nature and the requirement of teamwork in esports emphasizes the need for teams to be on the same page. While previous CSCW research has looked at esports through the lens of collective intelligence [55], our research focuses on team cognition and the processes required to develop a shared mental model required for these team interactions. Since team cognition requires a certain amount of communication [67], team cognition within the esports context can prove challenging. Prior studies have emphasized the importance of both annotation interfaces and pings to better communicate in this challenging environment [8, 104]. Such forms of communication have been identified as part of a larger framework that outlines awareness cues that can be made available to esports players by game designers to promote common awareness [103]. Even with these communication tools available to players, the fast-paced nature of esports can make it challenging for teams to communicate effectively in-game to determine the best team decision. Our findings indicate that quick decision making often requires a centralized leader to support this rapid coordination process.

Prior research has indicated that teams often rely on tacit coordination during fast gameplay [55]. Building on this work, our findings show how leadership factors can support this tacit coordination by affecting both the shared mental model and communication within the team. Previous literature has revealed leadership to be a core component of teamwork [86]. Based on our interviews we identified different types of esports team leaders including external leaders (e.g., coaches), shot callers, and even multiple leaders within the same team. Though the importance of these leaders often revolved around their critical role in making decisions and communicating information quickly, other benefits of leaders were revealed. We found that esports leaders often play a crucial role in forming how the team thought about the task or strategy. In this way, an esports leader has the capability to help sculpt the team into having a mental model that resembles their own. This approach, which occurs through discussions both in and out of game, has the potential to develop a team with a highly similar shared mental model. However, this shared model could be limited if the leader's mental model of the task and team are inaccurate [65]. These findings extend prior research on online multiplayer game by showing additional benefits to leaders forming and sharing strategies with their teammates [9, 56].

One way that strong leadership limitations can be mitigated is by leaders encouraging other team members to articulate their views of the task and team [15]. As team members share their own views, the leader's misconceptions may decrease which could result in a more accurate team mental model. This very phenomenon was realized by esports players who emphasized cultures of open communication and positive team interactions. Not only is the leader communicating their mental model to the team, but each team member has the opportunity to express their perspectives and improve the overall shared mental model. This understanding of how team mental model accuracy

can benefit from shared leadership contributes to prior work indicating that shared leadership positively influences team performance [44].

However, due to the fast-paced nature of esports play, it can be challenging for this reciprocal communication to occur during gameplay. In this way our findings support the work of Lim and Klein (2006) who found a direct relationship between mental model similarity and team performance [65] in contradiction to previous findings that only indicated a direct relationship between mental model accuracy and team performance [68]. Importantly, Lim and Klein hypothesized that this difference in findings was due to the "high stress and intense time pressure" [65] involved in the context of their study. The context of our study excellently mirrors this stress and time pressure. For many participants, there was a priority to have a strong singular leader in order to ensure a similar mental model between teammates. This leadership model also has the ability to alleviate inefficiencies associated with informal leadership as well [33]. On the other hand, some participants preferred a more fluid leadership style. This is likely due in part to some teams having the ability to communicate and make plans outside of the time constraints of the game. In this way, teams can gain both an accurate and similar mental model.

Importantly, since competitive esports teams often meet offline [28], we found that some teams are able to democratize decision making by planning and preparing before and after games. This is similar to CSCW simulation research that described the importance of debriefing as a team after simulations [47]. Esports teams are better able to collaborate, share perspectives, and thus reach better decisions when communication additionally occurs outside of the game. This strategy was mainly shared by players who met physically. However, many players described how pre- and post-game lobbies gave teams the opportunity to debrief and strategize outside of the rushed time constraints in-game. These findings can be applied to broader CSCW virtual team contexts if these teams must coordinate in tasks that are fast-paced in nature. Considerations can be taken in order to facilitate virtual debriefing to compensate for limited coordination during the task.

5.3 Design Implications for Team Cognition in Collaborative Virtual Teams

Based on our findings, we now provide potential design implications to address challenges associated with establishing team cognition within fast-paced virtual environments: 1) creating shared teammate understanding with new teammates; 2) streamlining communication within fast-paced environments; and 3) supporting a shared mental model through reflection. We explore ways in which team cognition can better be supported within esports teams while also suggesting design implications for other fast-paced virtual team contexts.

5.3.1 Using pre-game lobbies and "matchmaking" to establish teammate understanding. Based on our findings, mutual understanding of skills and personality was identified as a key component for team cognition for esports players. However, our participants often discussed the challenges involved in gaining this understanding when being matched with random teammates which is similar to previous work that has indicated that people prefer collaborating with friends rather than strangers [9] and that collaborating with strangers requires extra effort regarding social interactions [56]. In order for virtual collaborative spaces to facilitate team cognition quickly between teammates who are strangers, intentional design decisions must be made.

One design implication is to apply lessons learned from the well-established esports feature of role selection within the pre-game lobby. Since the task within esports is so fast-paced, players must maximize their time during role selection in order to better understand their teammates before the task begins. Not only does role selection facilitate conversations regarding strategy, it also specifies which role each teammate is assuming. This establishment of roles allows players to predict interdependencies between one another during gameplay based on their previous experiences.

Thus, virtual collaborative spaces should implement pre-task lobbies to account for teammates who might be strangers. The interface for such a lobby should facilitate a process in which teammates can discuss and select well-defined roles associated with the upcoming task.

Another design implication for establishing teammate understanding with strangers is to improve matchmaking algorithms. As most esports matchmaking algorithms only account for player skill level when making teams [4], other facets should be considered. Since esports players often have team roles they prefer to fill, the algorithm should account for building teams with players that have complementary role preferences or complementary skills. Though a rigid implementation of this algorithm could result in increased queues, flexibility could be built in to allow for team pairings with overlapping roles. For example, since most teams will inevitably contain a matching of more than one "Attack Damage Carry" teammate, the matchmaking algorithm should provide a pseudo "pecking order" for this role which can factor into the draft order. Other improvements to the matchmaking algorithm should account for compatibility of game strategy, personalities, and preferences towards levels of toxicity. If these considerations are taken when forming teams, teams can then gain an understanding for one another and establish common ground faster.

5.3.2 Using focused communication to avoid distractions within chaotic environments. An interesting component of esports is the necessity for communication and collaboration within a chaotic environment that makes communication challenging. Due to the fact that each teammate has their own set of incomplete information, developing refined sharing behaviors is essential as has been highlighted by prior researchers [8, 59, 103, 104]. Expanding on this research, we propose that esports players should additionally be able to maximize the amount of information shared with teammates who need it while minimizing sharing excessive information that could prove distracting. In order to streamline computer-mediated team communication within such fast-paced environments, design considerations should be taken to either: a) provide an interface so that players can selectively decide who they are sharing what information with or b) implement an algorithm for communication filtration so that teammates only receive information important to their role.

In most team contexts, an interface for selectively sharing information would be preferred in order to allow for more control. Team members could select a specific teammate or group of teammates in order to share information that is relevant to the teammate(s). Thus, teammates that do not require the information being shared will not be distracted by the sharing or become callused to the sharing of redundant information.

However, this interface could prove problematic in fast-paced environments as it requires an additional step for selection before sharing information. In these contexts, automating the sharing process could prove more useful. Though automating verbal communication would require advanced language processing, filtering other forms of communication would be easier. Since esports heavily relies on visual communication like pinging [59], communication software could filter pings based on location or object selected so that it is only shared with teammates requiring such information. Either way, esports players and virtual teammates would benefit from such design considerations which highlight the need for streamlined and less distracting communication.

5.3.3 Leveraging review tools to assist teammates in developing a shared mental model. Our findings also suggest that esports players benefit from the ability to use after action review tools to further increase the similarity of their shared mental model. Though much work has been done to highlight the ways in which teammates can gain a shared mental model during the game [8, 59, 103, 104], much can be gained by players dedicating time outside of the game to achieve a shared mental model with higher accuracy. Unfortunately, the replay features available to most esports games are not

designed with teamwork in mind. Specifically, these replay tools should allow for synchronous side-by-side displays of each teammate's perspective. When looking back at game footage as a team, team members can then gain a better understanding of the entire team's perspective and what challenges were present in executing a strategy. This review process can also result in increased empathy as team members gain an understanding for the challenges their teammates are experiencing in-game and how they might be able to better assist their teammates in the future. Further, this process of observing teammates can assist in the development of team cognition as teammates are able to better predict actions and reactions of their teammates during specific situations. Another feature that should be included in review tools is the ability to hear and see the communication that is occurring in-game. In this way, teams can observe and discuss communication breakdowns or when a teammate could have benefited from a missed call-out.

5.4 Limitations

Several limitations of this study should be noted. First, it is important to note that all participants were male, most of which around the typical age of college students. As mentioned previously, the esports community notably has issues with female representation in collegiate esports [1] and popular competitive esports genres [105]. Much research has investigated contributing factors to this disparity including the overwhelming majority of professional and highly visible players in the community being male [74], sexual harassment that female players receive [83], and the active marginalization of female competitors [74]. Importantly, this gender difference is not due to differences in ability to accrue technical skill [79]. Future work would benefit from better understanding how females overcome obstacles to participate in team cognition in a male-dominated context such as esports. Specifically, females are less likely to use voice chat due to harassment and are more likely to fill support roles [79].

Second, participants discussed their experiences from many different esports games. Since esports games have diverse mechanics and dynamics in terms of teamwork (e.g., communication affordances and interdependency of roles), future work should take the different gaming environment into account. Third, the data for this study solely relied on interviews. Since interview participants volunteered, a potential bias may be present for esports players with more sociable or collaborative tendencies. Last, a limitation of this work is that it solely relies on self-reported data. More data sources should be included in future work to verify the findings of interviews.

6 CONCLUSIONS

Based on previous theories of team cognition, its facilitation, and its importance to team performance, we have used esports as a unique context to better understand how team cognition is experienced and supported in a dynamic fast-paced environment. Since esports gameplay is highly dynamic and strategic we found that esports players required both a shared awareness of the game as well as a mutual understanding of teammate skills and personality in order to develop team cognition. Due to the intense level of stimulation in-game, players must use this awareness and understanding to inform what information they share and who they shared it with.

We also identified ways in which team cognition can be supported in esports. In addition to relying on experience with their teammates to assist in predictive behaviours and decision making, esports players also used experience with the game itself in order to develop team cognition with new teammates. Since esports game developers often include roles and role dependencies into their games, esports players can use their experience with the game and their understanding of roles in order to accelerate the onboarding of new teammates and the team cognition process. Further, we found that esports players used communication behaviors, preparation strategies, and social atmospheres as a means to develop a shared mental model. Due to the chaos and fast-pace

involved with esports, this shared mental model plays a crucial role in teams being able to predict teammate behaviors and support one another appropriately while simultaneously limiting verbal communication which can be distracting.

In summary, as both work and leisure activities continue to rely on online interactions, an ever-increasing understanding of virtual collaborative interactions is required. Our findings contribute to a better understanding of how computer-mediated collaboration can better realize the cognitive process of team cognition to increase team performance. Further, this work sheds light on ways in which team cognition can be formed under challenging circumstances including fast-paced tasks, stressful environments, and teams formed with strangers. We also provide implications and suggestions for online collaborative designs to better support team cognition in the future.

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