Investigating Communication Patterns as Proxy Indicators of Team Cohesion in Ad Hoc Teams

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Thesis Abstract

Team cohesion is a well-known facilitator of effective team functioning. However, there is a lack of empirical evidence identifying predictors of cohesion due to limitations in measurement methods. To address this issue, I propose that teams in digital games can be used as an alternative naturalistic environment to investigate team cohesion.

In this thesis, I present three studies that use a variety of experimental and analysis techniques to identify behavioural indicators of cohesion and show the value of digital games as alternative paradigms for investigating team dynamics. *Chapter 3* describes a qualitative study on identifying potential predictors of cohesion. The study is conducted from the perspective of an intention to be on the same team in the future. The findings from *Chapter 3* suggest that team communication may be a key factor that influences intention for repeated play between strangers in ad hoc teams.

Chapter 4 and *Chapter 5* explores team communication as a proxy indicator of cohesion to identify precisely what and how communication influences or indicates cohesion. In these studies, we first establish the relationship between cohesion and performance (Chapter 4 and 5), and between cohesion and satisfaction (Chapter 5). This ensures that the findings on cohesion in digital game teams are comparable to the wider cohesion literature. Once these relationships are established, we investigate how different communication metrics are related to cohesion and team outcomes (e.g., performance and satisfaction). Performance and satisfaction were chosen as outcome measures as these represent well-known outcomes that are generated by cohesive teams as they develop. *Chapter 4* and *Chapter 5* provide insight into the relationships between cohesion and team outcomes, and the relationship between communication and cohesion, in different team contexts.

Chapter 6 closes with a discussion of the observations, findings, and new knowledge gained from this research expedition on identifying a potential unobtrusive behavioural indicator of team cohesion.

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Acknowledgements

This has been good fun. Although the PhD might well be the most difficult thing I've ever done, it has also been the most freeing experience of experimentation, failure, and learning. I've thoroughly enjoyed blending my passions with my hobby – combining games with my curiousity of teams.

This journey would not have been possible first and foremost without my parents, whose early convictions to send me to the UK for undergraduate paved the way for this opportunity. I suppose my brother Alex Tan played a part in this because he was the guinea pig that went before me to show that the UK was a good place to study! Growing up in Malaysia, it was (and is still) wild to think of doing a PhD on digital games. This is not a path I would have considered (or been aware of) if I hadn't moved to York when I was 19.

This leads me to thank Prof. Alex Wade, who I met during undergraduate when he gave a lecture on research methods and presented data from League of Legends. It was through meeting him and his then PhD student, Athanasios 'Naz' Kokkinakis, that I had my first taste of games research and loved it!

I think my brother Ryan Tan and our good friend Gregory Ho also have a part to play in how I ended up here. It was because of their patience and generosity of teaching me how to write a basic python script for API scraping that gave me enough confidence to apply for the IGGI program in 2018 in the first place.

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shine, and for forcing me to unplug. You are the best doge and I’m glad I could share this journey with you.

Author’s Declarations

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

Conference publications from work presented in this thesis:

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Chapter 1 Introduction

1.1 Statement of the problem

Ensuring that teams operate effectively has been important ever since humans began operating in groups. In the modern world, teams[1] are a vital component of essentially all organisations (e.g., hospitals, schools, corporations, sports, military, healthcare). Team effectiveness has been studied formally for over a hundred years in order to identify and optimise team functioning [4]–[6]. This thesis is largely focused on a fundamental attribute of team function: 'cohesion'.

Cohesion is one of the most widely researched topics in the team effectiveness literature, with eight meta-analyses on the subject in the past 30 years (some examples include [7]–[12]). Cohesion has been defined in various ways, for example, “The bond between members of a team that elicits a desire to remain and work together.” [13], “Team members’ shared commitment or attraction to their task/goal and to one another.” [14], “The tendency for a group to stick together and remain united in the pursuit of its instrumental objectives and/or for the satisfaction of member affective needs.” [15], and “The total field of forces which act on members to remain in the group. These forces may depend on the attractiveness or unattractiveness of either the prestige of the group, members of the group, or the activities in which the group engages.” (p. 274. [16]). These definitions centre around two key notions: (1) that cohesion reflects some form of bond or attraction – driven by either the team’s tasks and/or the relationship with team members, and (2) that this bond or attraction inspires continued commitment/causes a team to remain together.

Cohesive teams have higher performance, and their members tend to report higher levels of satisfaction, perception of viability, and greater intention to remain in the team [2], [17]. These findings stem from domains including sport [11], [18]–[20], defence [21]–[25], and business [26]–[28], and more recently includes studies that

[1] “a distinguishable set of two or more people who interact, dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission” ([1], p. 4)

have investigated cohesion longitudinally [14], [27]. Clearly, cohesion is important. However, while the *outcomes* of cohesion have been investigated heavily, much less is known of its *predictors* [4], [13]. In their review of the literature, Kozlowski and Ilgen [4] concluded that "the research base to help identity techniques for enhancing group cohesion is as yet not sufficiently developed to warrant specific recommendations for how to develop [this] desirable emergent [state]". More than a decade later, there is still little progress in this research area [29], [30]. This poses a challenge for practitioners trying to facilitate and develop team cohesion. Several important questions remain unanswered, such as: What factors lead to high team cohesion? Do cohesion levels change over time? What does the growth trajectory of cohesion look like? What factors mediate the development of team cohesion? Answering these questions will inform how evidence-based interventions to improve cohesion across domains are designed. It could also feed into predictive models that simulate the cohesion trajectory and success of a high-risk team before the team is formed. For example, such technology could ensure higher safety and mission success for space teams, provide a blueprint of training needs for coaches and managers of competitive esports teams, or inform frameworks for developing cohesion in unfamiliar military units and healthcare teams.

Understanding how team cohesion can be facilitated and how it develops over time may be particularly important for teams that operate in extreme, high-risk environments where poor team functioning has life or death consequences. Teams that operate in these environments may also be temporary or 'ad hoc' teams that form because of crisis events (e.g., emergency medical teams). Nonetheless, cohesion has been found to enable high risk teams such as military units and special operations police to persevere under adverse conditions [24], [31], [32]. Similarly, there is growing interest to investigate how to facilitate and maintain cohesion in long-term isolated teams such as those in space exploration missions or Antarctic expeditions [33]. For these teams, maintaining strong interpersonal relationships and ongoing commitment to the task in isolation will enable them to persevere under inevitably difficult working and living conditions, persistent danger, and a wide range of other challenging stressors [33], [34].

One of the main reasons for the gap in the knowledge on establishing and developing team cohesion is the disconnect between how teams are conceptualised versus how they are studied and how constructs are measured. Teams are dynamic: their function and development is influenced by feedback from their experiences (with the environment and/or with each other) over time. While there is consensus on how teams are conceptualised – as complex, dynamic, adaptive, systems [35] – in practice, many study designs and research methodologies do not capture or account for the effect of time. In other words, while teams are in fact dynamic, they have largely been treated and researched as static entities. This is evidenced by the fact that cohesion has primarily been investigated using self-report measures, with the Group Environment Questionnaire (GEQ) being the most widely used [36]–[39].

While self-reported measures are cost-effective and easy to administer, they are limited tools for measuring constructs with temporal dynamics. Although one could argue for taking measures at multiple time points or pausing the team task to complete the survey, for some teams, this is often difficult. This is especially true for fast-paced, dynamic, or high-risk team settings such as emergency medical teams or ad hoc military units where it is impossible to stop mid-task. Moreover, as team cohesion is a perception, that depends on the time at which the measure is taken, it may be influenced by feedback from a team's environment (i.e., if they performed badly, members may perceive low cohesion and vice versa). In other words, team members may attribute poor performance to poor cohesion when in fact there were other causal factors at play. To address these methodological issues, researchers are encouraged to develop unobtrusive behavioural indicators of cohesion [29], [37], [40]. It should be noted that these issues are not exclusive to team cohesion. A recent review on the literature of team emergent states (which includes team cohesion but also other stats such as trust and team cognition) found an overall lack in how different team states emerge, with mixed findings on how emergent states increase, decrease, or fluctuate [41]. This makes it difficult to systematically cultivate emergent states that have a positive effect on team functioning (such as cohesion).

For these reasons, researchers have been encouraged to develop unobtrusive behavioural indicators of cohesion [40], [42]. This will enable cohesion to be investigated over time and free from perceptual biases. Examples of such indicators include social network analysis of relations in a team [43], [44], physical proximity metrics via sociometric badges [45], [46], and analysis of text or verbal exchanges [47]–[49]. This field of research is in its early stages and still requires the complementary use of the more traditional but better validated survey measure of cohesion to ensure construct validity [37]. Nonetheless, the literature is moving in the right direction in focusing resources on developing unobtrusive behavioural indicators of cohesion. Once validated, these measures will allow researchers and practitioners to understand how cohesion emerges and how it can be systematically cultivated to support effective team functioning. In an era where teams have become vital to both work (e.g., hospitals, schools, corporation) and play (e.g., multiplayer digital games, sports), understanding the predictors and correlates of team cohesion is an important and timely problem.

1.2 Rationale for the current thesis

This thesis contributes to the ongoing effort of developing unobtrusive behavioural indicators of cohesion with a particular focus on *ad hoc* teams of strangers in digital games.

1.2.1 Why *ad hoc* teams?

In this thesis, I investigate *ad hoc* teams of strangers — teams that come together for a short period of time and disband once the task is complete, and whose members are unfamiliar with each other or have no prior experience working together; also known as *swift starting action teams* (STATs). Examples include crisis management units [50], [51], military units [52], [53], and emergency response teams [54], [55]. There are two reasons why ad hoc teams were chosen: Firstly, ad hoc teams likely cycle through multiple performance episodes in a short amount of time. A performance episode is a complete cycle where teams plan and execute an action toward an objective. The feedback from this cycle not only informs how future cycles are enacted

but also influences emergent states like cohesion [30], [56], [57]. This provides an opportunity to investigate how cohesion perceptions form and change in response to external events (see Section 2.1). Secondly, ad hoc teams are newly formed teams and generally have low familiarity. This context allows us to study how cohesion emerges and develops across the entire team life span, from inception until they disband. As described above, teams are dynamic and team functioning changes according to feedback from the (internal/external) environment. Since cohesion reflects some form of bond or attraction driven by either the team's tasks and/or the relationship with team members, investigating newly formed ad hoc teams with members who lack prior relations enables us to identify factors that influence cohesion emergence in the *first instance*, and potentially minimises the influence of feedback on cohesion perceptions.

1.2.2 Why digital games?

We use digital games as the domain of investigation for several reasons. There is evidence that digital games are a valuable platform to address research gaps in the team literature due to the **parallels between teamwork demand**s in games and real-world team environments [58]–[60]. Digital games also provide **naturalistic team environments** that allow **behaviours to be unobtrusively tracked** over time, and. provide an avenue for researching teams from their inception until they disband. Due to their digital nature, people often play and communicate remotely in digital games. In addition, games have clear objectives and quick feedback loops. This creates a unique environment where data sources which are not usually easy to capture or analyse in physical environments, such as the state of the environment, impact of actions, and communication activity, can be accessed. Moreover, since games have clear goals, one can argue that digital games have the additional benefit of providing controlled environments for investigating teams, in the sense that teams are always working toward the same goal and there are clear, objective measures of goal attainment, which may not always be the case in real-world environments. Finally, digital games are played by millions of people around the world [61], [62]. This potentially provides easier access to participants – an inescapable logistical challenge of team research.

1.3 Research questions

Although this thesis investigates ad hoc teams of strangers in *digital games,* research decisions, design, and methodology are based on and inspired by the non-digital game literature on teams. The hope is that the findings and insights generated through the exploration of potential unobtrusive, behavioural indicators of cohesion within the digital game domain can benefit and have wider implications for supporting effective team functioning in real-world teams. As such, this thesis is driven by the following research questions.

> **RQ1:** What factors influence cohesion in ad hoc teams of strangers in digital games?

RQ1 was addressed through a qualitative study on potential predictors of team cohesion. In this study, team *communication* surfaced as a prominent factor that potentially influences team cohesion. Therefore, the remainder of the thesis focused on analysing the relationship between communication and cohesion.

> **RQ2:** Can team communication be used as a proxy indicator of cohesion?
>
> - If so, what communication metrics best indicate team cohesion

It should be noted that as the research decisions, design, and methodology was based on and inspired by the non-digital game literature on teams, it was also important to establish the relationship of cohesion with well-known team outcomes such as performance and satisfaction. Moreover, if we are to build a case for using digital games as a lens to study real-world swift starting action teams, we need to ensure that the relationships observed in real-world STATs is replicated in digital game STATs. This will enable findings from digital games STATs to be generalised to the real-world. Therefore, the empirical studies of this thesis also investigate how cohesion is related to performance and satisfaction.

RQ3: Is cohesion linked to outcomes such as performance and satisfaction in digital game teams, as has been shown in non-digital game teams?

1.4 Thesis contributions

This thesis takes an innovative approach to cohesion research by using digital game teams that match the task complexity, role specificity, and time pressure that real-world swift starting action teams face (Figure 1). Investigating cohesion in STATs has been challenging because "… in these settings, self-report measures (the dominant method for measuring team cohesion) may be cumbersome or practically impossible to administer" [37]. By using swift starting digital game teams, I made a substantial original contribution to expanding the knowledge on team cohesion both in and out of digital game teams. In this thesis, I identified behaviours that gave rise to team cohesion in swift starting digital game teams via a *qualitative* study. I then used a *quantitative* method to identify communication metrics that reflect the behaviours that were qualitatively identified. This thesis highlighted a method for analysing team communication as a proxy indicator of cohesion. This allows future researchers to extend the method and findings from this thesis to identify cohesion-building behaviours that may generalise to real-world swift starting action teams (STATs). Therefore, this thesis makes three main contributions to the cohesion literature:

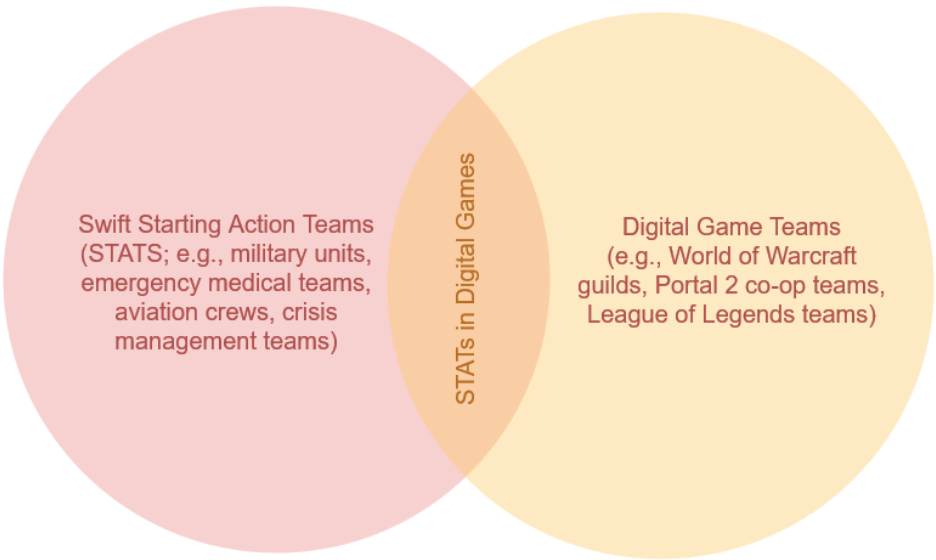

Figure 1 STATs in digital games.

Venn Diagram shows the overlap between characteristics of digital game teams and swift starting action teams (STATs). Teams in digital games differ based on their game genre and game design. In this thesis, we focus on a subset of teams in digital games and only include games with teams that share the characteristics of STATs (i.e., ad hoc, perform immediately under evident time pressure).

1. **I show that digital games are viable research environments** to investigate cohesion providing the team context in the games matches that of real-world teams. This adds to a nascent body of work showing the value of digital games as naturalistic research environments to study real-world team phenomena [58], [63]. This also validates the 'digital games as an alternative research paradigm' perspective outlined by Steve Kozlowski [57] as one of the new methods needed to advance research on team dynamics. In addition, the interactions between team members, within-team events, and outcomes can be tracked in digital games, which addresses the additional challenges to investigating team cohesion over time [29], [40].

2. **I collected the largest quantitative dataset of team communication** in esports and gaming**.** Within esports and gaming, studies of team communication have almost exclusively been qualitative [64]–[67]. Without quantitative data, researchers were previously unable to identify the actual manifestations of team dysfunction (as reflected in the communication dynamics) or verify the retrospective interview responses provided by participants. However, in this

thesis, I have collected the largest quantitative dataset of team communication in a popular competitive game, *League of Legends* [68], which researchers are able to access for future work.

3. **I identified potential cohesion-building behaviours** that arise in teams that are newly formed or ad hoc. These manifest in team communication. The findings suggest that communication frequency is correlated with cohesion, which validates previous research showing that cohesion is influenced by communication frequency [69], [70]. The findings also suggest that the content of communication is not correlated with cohesion, but the interactions between team members might be. This thesis has provided initial behavioural evidence of cohesion and generated testable hypotheses on the communication-cohesion relationship.

4. **I show the value of using sequence analysis** to investigate the interactions between team members. In the military and aviation domain, sequence analysis has been valuable technique for building a comprehensive picture of communication in teams [71]–[73]. This technique has been underutilised outside of those domains, and especially in games research. While the technique has limitations, the findings from using sequence analysis suggests that there may be differences in the interactions between team members of cohesive versus non-cohesive ad hoc teams.

1.4.1 A Note for Future Work

It should be noted that this thesis merely scratched the surface of identifying predictors of team cohesion. The initial goals of this thesis – to investigate cohesion longitudinally and identify predictors – are still open to investigation. Nonetheless, the thesis highlights the value of digital games as a promising avenue for investigating team cohesion, identifies potential cohesion-building behaviours that can be used to generate and hypotheses, and outlines a method to investigate cohesion (and potentially other emergent states) in digital teams.

Through this investigation, here are three recommendations for future research:

1. Define and operationalise cohesion in line with the rest of the cohesion literature for comparison and generalisability.

    Lack of previous empirical evidence of predictors from other domains, and the dearth of team cohesion research in the gaming and esports literature where cohesion is defined and operationalised consistently with the rest of the cohesion literature, meant that the empirical studies conducted were approached predominantly through an exploratory lens. The studies in this thesis should be treated as a perspective in which team cohesion, and by extension other team emergent states, can be analysed in digital games, and generalised to the non-digital games domain.

2. Prioritise industry partnerships.

    Team communication is an incredibly rich data stream that is currently untapped. I speculate that this is due to the laborious effort related to collecting and cleaning such data. Industry partners such as *Discord* may aid this data collection process given the millions of gamers who use their platform for voice communication every day. On the other hand, industry partners with research labs such as *Riot Games* and *Sony* may have additional resources to accelerate the data cleaning process. In general, prioritising industry partnership will enable research outputs to increase exponentially.

Chapter 2 Literature Review

In the previous chapter, I introduced the concept of team cohesion, touched on its importance and highlighted the current challenges that are hindering our understanding of how team cohesion can be systematically cultivated to support effective team functioning in ad hoc teams. This chapter will discuss:

- How cohesion is conceptualised and where it fits within theories of team functioning
- How cohesion is (or should be) measured
- What the current measurement issues are
- How researchers have been trying to address these issues

2.1 How is cohesion conceptualised and where does it fit within theories of team functioning?

Team cohesion is characterised as a team emergent state with task and social dimensions [10], [74]. Task cohesion refers to the attraction or bond within the team because of a shared sense of commitment and unity toward achieving the team task or goals [12], [75]. High levels of task cohesion indicate that team members are united and “on the same page” regarding their performance goals. Social cohesion refers to the attraction within the group because of positive relationships with other members of the group [12], [75]. It reflects shared bonding and liking among team members.

In theories of team functioning, emergent states are characterised as ‘mediators’ that support teams in converting inputs (such as the composition of members’ expertise, team context, organisational structure) into outputs (such as performance and member satisfaction) [4], [56], [76], [77]. In the literature, a team construct is considered as an emergent state if (1) it does not exist prior to the formation of a team, (2) it emerges and varies as a function of the interaction within the team and is shaped by the team outcome and subsequent team processes, (3) it is a dynamic property, that is, it can change in magnitude and form at different time

points, and (4) it reflects a shared, team-level phenomenon [30], [74], [78]. Emergent states are distinct from observable team processes (that is, actions and behaviours that team members perform) because they "tap qualities of a team that represent member attitudes, values, cognitions, and motivations" (p. 357) [56]. There are different types of emergent states such as affective-motivational states (e.g., cohesion, collective efficacy) and cognitive states (e.g., shared mental models, transactive memory).

2.1.1 Teams operate in episodic cycles

A critical inflection point in the team effectiveness literature occurred when Marks and colleagues [56] made the distinction between emergent states and team processes, and when they proposed that teams operate in episode cycles known as 'performance episodes'. This work was a critique and extension of the Input-Process-Output (I-P-O) model by McGrath [79] which guided early investigations of how teams combine their knowledge, skills, and expertise to achieve team goals. The I-P-O model posits a sequential relationship between inputs and outputs, where inputs lead to processes that in turn lead to outputs (as depicted by the hyphen between the letters; see Figure 2).

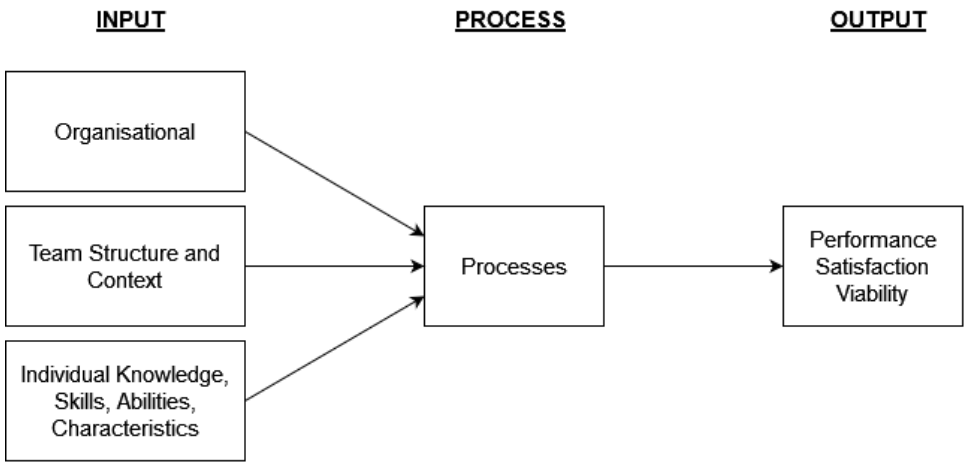

Figure 2 McGrath (1964) Input-Process-Output (IPO) framework.

In this framework, there is a linear progression from inputs to outputs – inputs lead to processes that in turn lead to outputs.

In their review of the team effectiveness literature at the turn of the century, McGrath et al. [80] highlighted that the limitations on the meaning and generalisability of findings from studies on team effectiveness were driven by several factors. They state:

- Teams were studied as if they were simple systems, composed of chain-like, unidirectional, cause-effect relations.
- Teams were studied as if they were isolated from their embedding contexts.
- Teams were studied as if they were static entities, with no past, no future, and only an input-output present.
- Teams were studied as generic entities made up of generic people, as though all people and all groups are interchangeable.

It was at this time that teams began to be viewed as complex dynamic adaptive systems. Instead of being static entities that are unchanged by experience, teams are constantly adapting to their environment and feedback from the environment, and make decisions based on the team's history and expected outcomes of the future [35], [80].

Building on this work, Marks et al. [56] proposed that teams operate in 'performance episodes' where the outcomes of each episode becomes inputs for subsequent episodes, implying that team behaviour is influenced by prior experiences together. In addition, Marks et al. [56] further outlined what performance episodes can look like: termed *transition phases* or *action phases* (see Figure 3). *Transition phases* contain processes related to planning and evaluation activities (e.g., goal specification, strategy formulation and planning) while *action phases* contain activities that lead directly to goal accomplishment (e.g., coordination, systems monitoring, and progress monitoring). These phases were used to illustrate the importance of different processes at different points of working on a team task. Supporting these transition and action phases are *interpersonal processes* such as conflict management, motivation/confidence building, and affect management. This temporal framework of team processes has been empirically validated since it was first proposed [81], [82].

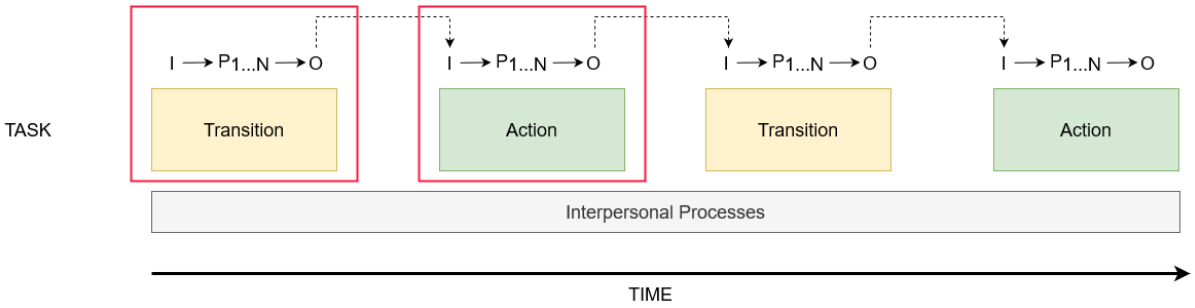

Figure 3 Marks et al. (2001) temporal framework of team processes.

An illustration of how a team addresses task demands over time based on Marks et al. temporal framework of team processes. A performance episode is depicted by the red outline and represents one cycle of the I-P-O sequence. When one performance episode ends, another is initiated. These performance episodes can reflect different processes: transition processes (yellow box) and action processes (green box). Transition processes are activities where teams evaluate prior performance and/or plan future actions. Action processes are the acts that directly contribute to goal accomplishment. Underlying transition and action processes are interpersonal processes, which represent the actions and behaviours that members use to manage interpersonal relationships in the team. This graph is adapted from Marks et al. [56].

Given this development, Ilgen et al. [76] introduced the Input-Mediator-Outcome-Input (IMOI) model to further emphasize the distinction between processes and emergent states, and the reciprocal influence of outcomes from one performance episode on subsequent performance episodes. This was further clarified by Mathieu et al. [77] in their review of the team effectiveness literature from 1997-2007 that proposed that outputs were more likely to have a stronger effect on subsequent processes and emergent states compared to its effect on team inputs. They argue that team (emergent) states are more likely to be influenced and teams more readily prepared to change and adapt their processes in light of performance feedback. In comparison, inputs such as the expertise of team members and the context in which the team operates are less malleable and thus less likely to be influenced by outcomes [77] (Figure 4). The combination of Marks et al.'s [56] distinction between team processes and emergent states, and Ilgen et al.'s [76] IMOI model has become a widely adopted organising framework when studying teams in different contexts [33], [83]–[85].

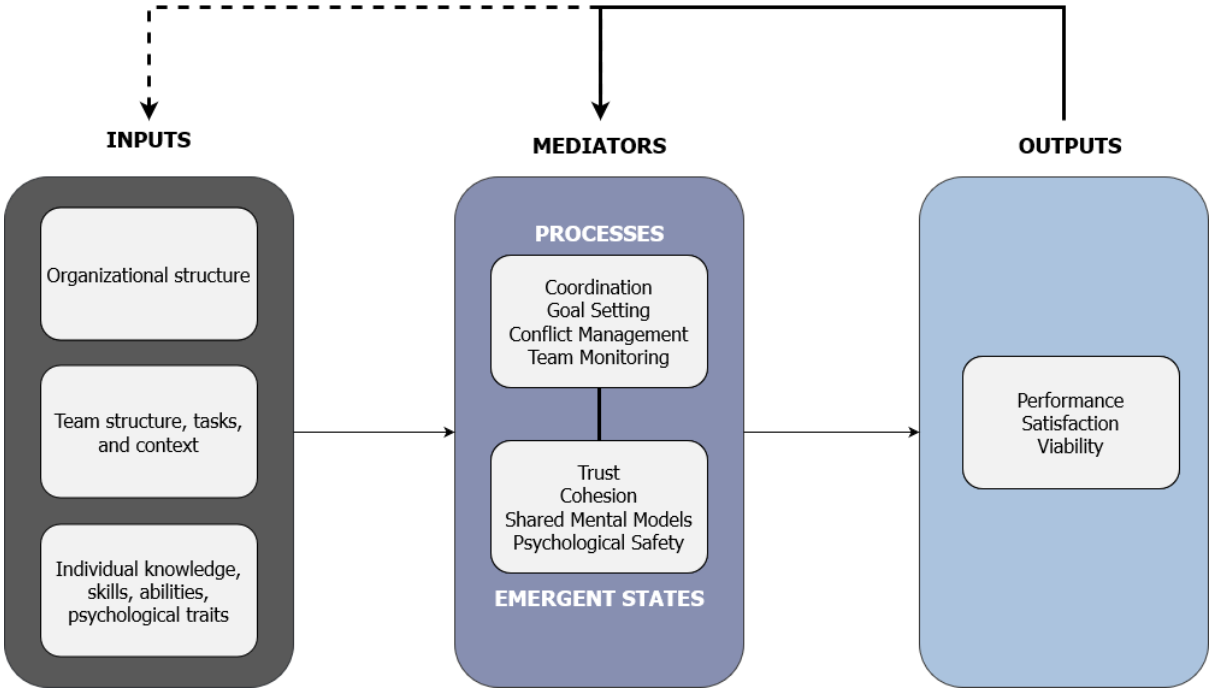

Figure 4 The input-mediator-output-input (IMOI) model by Ilgen et al. (2005).

The solid line shows that the influence of outputs is stronger on subsequent team processes and emergent states compared to the influence on inputs (as depicted by the dotted line). Note: the various inputs, mediators, and outputs are examples and not an exhaustive list of factors.

2.1.2 The dynamics of emergent team phenomena

As a dynamic property, emergent states are not necessarily fixed across time. They can change in terms of how they are perceived in the minds of team members (i.e., within-team variability), the strength and magnitude of cohesion and its different dimensions and their growth trajectories over time [57], [86]. Research suggests that cohesion is less stable early in a team's life cycle and more difficult to capture using questionnaires because team members lack sufficient interaction instances to meaningfully perceive cohesion [78], [87]. Figure 5 illustrates how the degree that cohesion perceptions are shared among team members varies as teams are exposed to various internal (e.g., experiencing conflict in the team) and/or external (e.g., losing to an opponent) events. For example, when teams are exposed to a negative event or stressor, perceptions of cohesion may fragment but when the team overcomes the stressor, cohesion perceptions may become unified again [57].

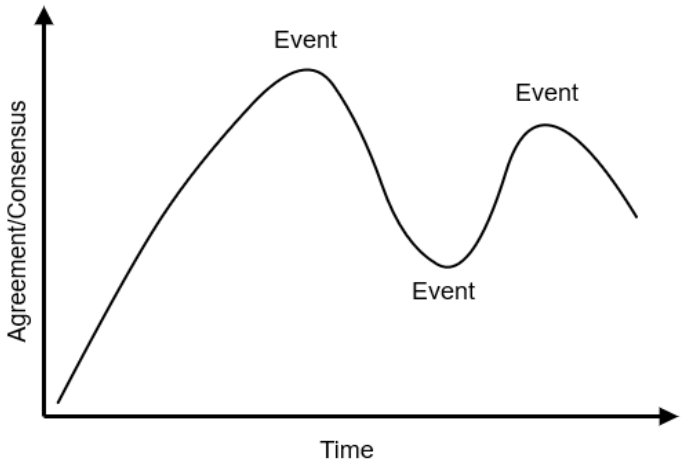

Figure 5 Within-team variability in emergent team phenomena.

The graph shows that across time, a team can have varying levels of consensus on team-level emergent phenomena (i.e., cohesion) due to the influence of external or internal events. Source: Kozlowski [57]

There is some evidence supporting this theoretical proposition that cohesion takes time to be perceived in the minds of team members and that it is relatively unstable in the early stages of a team [14], [27], [88], [89]. Mathieu et al. [27] conducted two longitudinal studies with student teams on a business simulation and found that cohesion interacts with time, as related to team performance. Specifically, the cohesion → performance relationship was not significant at Time 1 (β = .11, *SE = .07, p > .05; ns*), became positive and significant at Time 2 (β = .25, *SE = .11*, *p* <.05), and was strongest at Time 3 (β = .50, *SE = .17*, *p* <.001) (Figure 6).

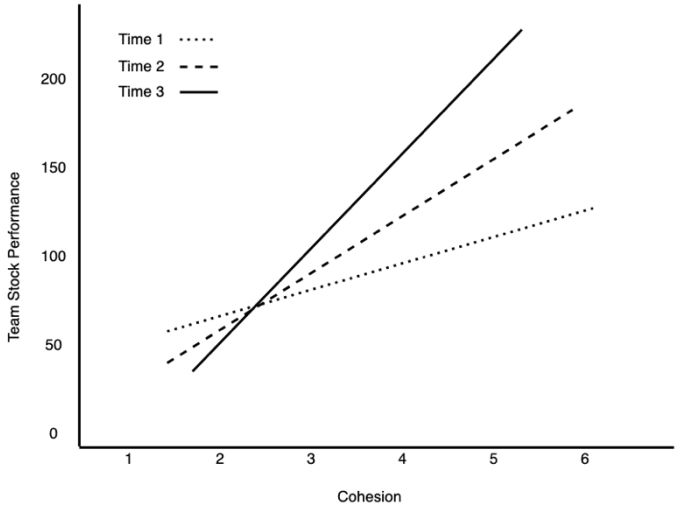

Figure 6 The cohesion-performance relationship over time.

Team Cohesion → Performance relations by Time interaction from Mathieu et al. [27] study. This figure shows that the strength of the cohesion on performance increases over time, as indicated by the increased steepness of the slope for each line.

Braun et al. [14] found similar results in their longitudinal study with student teams on a resource foraging simulation. They calculated the relative importance of cohesion for predicting performance across each experiment round (10 rounds in total). Their results showed that during the first half of the rounds, cohesion explained about ~8% of the unique variance in performance. This doubled to ~17% in the second half of the rounds [14]. The findings from these studies lend support to the proposition that early in a team's life cycle, cohesion is more malleable and more easily influenced by the outcome of events (e.g., performance) but over time, cohesion becomes more stable and less susceptible to feedback from the outcome of events. Specifically, it suggests that the magnitude of the positive influence of cohesion on performance *increases* over time, while the magnitude of influence of performance on cohesion *decreases* over time.

The level of cohesion in the team (i.e., growth trajectory) can also change over time [57]. For example, we may expect a well-functioning team to exhibit a monotonic increase in the level of cohesion over time. However, since cohesion, as an emergent state, has reciprocal relations with team outcomes (based on the IMOI model) the level of cohesion in the team can change. Figure 7a illustrates a typical monotonic increase in levels of cohesion over time, possibly as a team learns to effectively work together and experiences positive outcomes. In contrast, Figure 7b shows a team that is highly cohesive that has a downward trajectory of cohesion possibly due to the inability to recover from a series of setbacks.

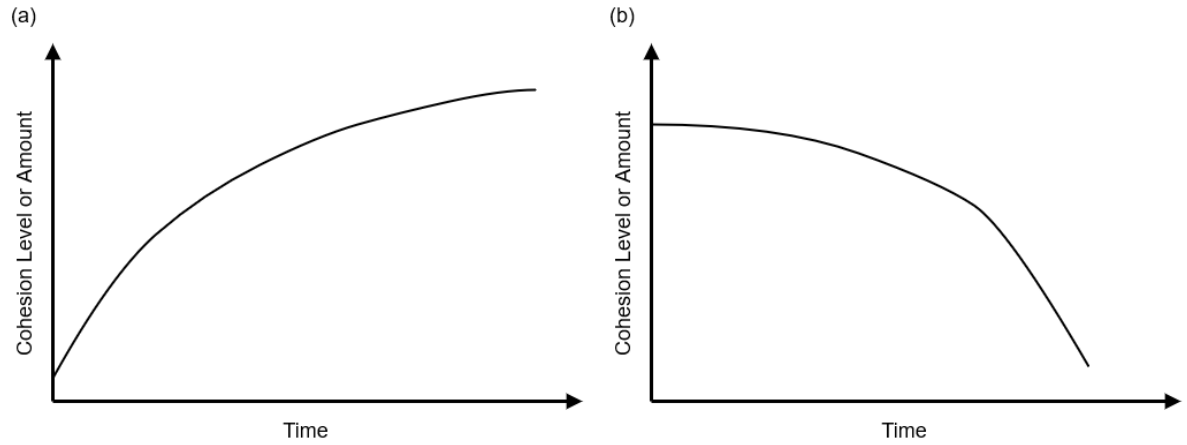

Figure 7 Growth trajectories of emergent team phenomenon.

Two examples of different growth trajectories in the level of emergent team phenomenon. A positive growth trajectory in the level of cohesion over time is shown in (a) and a negative growth trajectory in the level of cohesion over time is shown in (b). Source: Kozlowski, 2015 [57].

The task and social dimensions of cohesion are also thought to emerge differently over time. Carron and Brawley [90] state that while social and task cohesion both contribute to cohesion, it is likely that task cohesion is more salient in the early stages of a team's life cycle. Indeed, there is some evidence that not all cohesion dimensions are present or are equally salient throughout the life of a group. For example, Bartone and Adler [91] investigated cohesion in military medical units over a six-month period. Their results showed that cohesion was low during pre-deployment, high during mid-deployment, and levelled off towards the end of the deployment cycle. The authors speculated that pre-deployment cohesion levels could be attributed to the lack of familiarity in each unit (units had 3 weeks of training prior to deployment); at mid-deployment cohesion levels were attributed to the perceived competence of the leader (i.e., perceived concern, abilities, and effective communication); at late-deployment cohesion levels were attributed to the extent that leaders expressed concern (i.e., when a soldier has confidence that their family is being cared for) [91]. This is in contrast to the cohesion pattern observed in a similar study investigating cohesion in military units deployed over a six-month period – cohesion started high, dipped within the first sixty to ninety days, and then slowly increased over time [92]. In their review of years of military cohesion research, Siebold [93] argued that these conflicting patterns reflect the level of emergence and stability of different cohesion

dimensions such that the U-shaped cohesion pattern reflects *social cohesion* and the inverted U-shaped cohesion pattern reflects *task cohesion* (Figure 8).

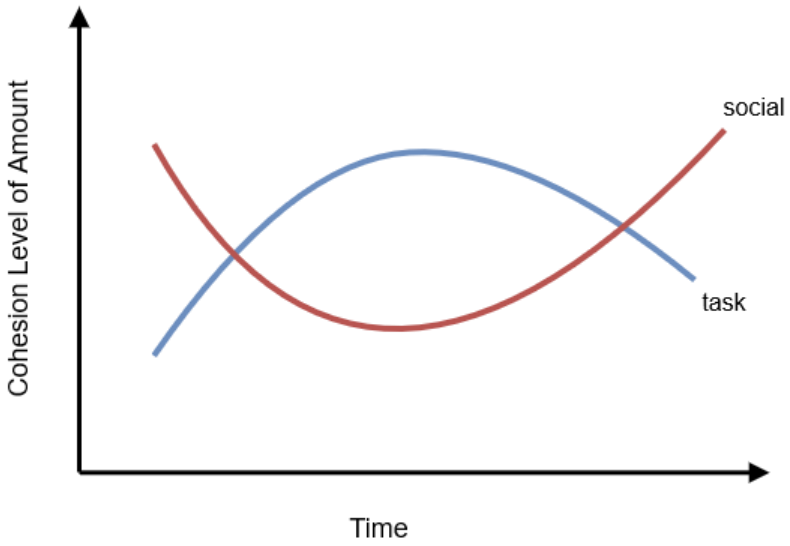

Figure 8 Trajectory of task vs social cohesion.

Illustration of how the trajectories of task and social cohesion change over time based on explanation by Siebold [93].

The temporal dynamics of cohesion and the variability in strength and magnitude of the different cohesion dimensions has implications on when cohesion is measured and what findings from measurements at different time points might mean [30], [57], [94]. This also has implications for the factors that predict cohesion and reinforce cohesion. For example, when investigating predictors of cohesion in newly formed teams, it makes more sense to focus on task-oriented predictors (e.g., coordination, task-focused communication) rather than social-oriented predictors since task cohesion emerges first [37]. Hence, it is important to understand the dynamic properties of cohesion and where cohesion is situated within theories of team functioning in order to theoretically link cohesion with its various predictors and mediators.

2.2 How is cohesion measured?

Team cohesion is primarily measured using questionnaires in studies with cross-sectional designs [29], [37], [40], [74]. There are many different cohesion questionnaires but one of the most popular cohesion measures is the Group Environment Questionnaire (GEQ), developed to investigate cohesion in ongoing sport teams [18], [36], [95]. The GEQ has a four-factor structure which contains both task- and social-dimensions of cohesion and has shown good construct validity and reliability in sport teams [11], [15]. The measure has also been adapted to non-sport contexts [9], [88].

However, it is not clear if the four-factor structure can be replicated or whether the model is a good fit to data when the GEQ is adapted to non-sport contexts. For example, a study investigating the factorial validity of the GEQ in a military context (consisting of different military divisions, ranks, and types of units) found that a four-factor structure was a better fit to the data compared to a one- or two-factor structure [21]. However, the model itself did not provide a good fit to the data (i.e., values of various fit indexes fell below the conventional standards for well-fitting models). Another study adapted the GEQ for work teams in Australian public sector retail outlets and could not replicate the four-factor structure [88].

One possible reason for this mixed finding is that cohesion is conceptualised as a team-level construct but the GEQ contains a higher-order factor that assess individual perceptions of cohesion (in addition to team-level perceptions of cohesion). To elaborate, the GEQ contains two higher-order factors: *Group Integration* (defined as “a member’s perceptions of the group as a totality”) and *Individual Attraction to the Group* (defined as “a member’s personal attraction to the group”) (Figure 9) [36]. Carless and de Paola [88] have argued that there is limited utility in measuring cohesion at the individual level since cohesion is a group-level construct. While Carron et al. [96] responded with empirical evidence that individual perceptions can reflect shared beliefs of cohesion, more recent analysis of the cohesion literature favours the measurement and analysis of cohesion at a team-level. For instance, Whitton and

Fletcher [38] were able to replicate the four-factor structure of the GEQ in their sample of 59 elite netball teams, but noted that the factor loadings were stronger at the group-level rather than individual level. In addition, a recent review on cohesion measures and analytical methods found that aggregating cohesion to the team level more frequently yielded significant findings (76% of measured relationships in the review) compared to cohesion analysed at the individual or dyadic level [37].

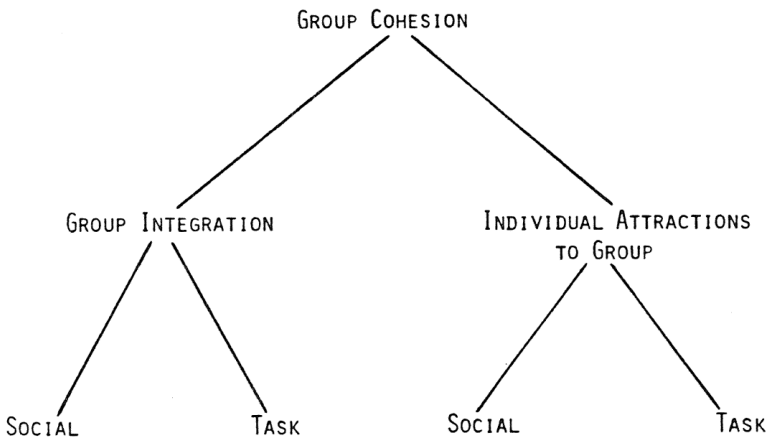

Figure 9 The GEQ four-factor structure.

The GEQ has two higher-order factors which refer to the perceptions of group cohesion (GI) and perceptions of individual feelings of cohesiveness (IAG). The higher-order factors are further broken down into the task and social dimension of cohesion.

On the other hand, although the GEQ has good psychometric properties, it was designed for long-standing teams and thus not suitable for ad hoc teams – which is the focus of the thesis. The GEQ is not suitable for ad hoc teams because the questions rely on members having collaborated for an extended period and with ongoing relations. As a result, researchers have developed alternative questionnaire measures for different types of teams and team settings [97], [88], [98]. Despite its criticisms and limitations, the GEQ remains as a widely used measure of cohesion.

2.2.1 Measurement issues with questionnaires and cross-sectional studies

While considerable progress has been made using traditional measurement methods (i.e., there is consensus on the positive influence of cohesion on team outcomes), it

has also created a critical gap in knowledge of predictors, interaction effects with other processes and emergent states, and boundary conditions of team cohesion [13], [18], [24], [29], [30]. The inherent problem with questionnaire measures is that they are unable to capture the *dynamics* of emergent phenomena. Questionnaires and cross-sectional studies provide 'snapshots' of cohesion. They cannot capture emergence or dynamics directly and treat cohesion as a static construct – one that is unchanged over time, which conflicts how cohesion, and team functioning in general, is conceptualised. Moreover, questionnaires are intrusive, require ongoing activity to be suspended for members to reflect, can be biased or risk responses being affected by the delay between the questions and the experience [37]. Cohesion is also often measured *after* a certain level of interaction between members has already occurred and rarely is cohesion measured more than twice [13], [18], [27].

This is problematic for several reasons. Since cohesion emerges as a result of the interaction between team members and their environment [30], [74], [99], measuring cohesion *after* a certain level of interaction between members has already occurred makes it difficult to identify exactly what or how the interactions gave rise to cohesion, and at what point cohesion emerged; it is difficult to identify the predictors of cohesion. On the other hand, when cohesion is measured only once or twice, it is not possible to capture the fluctuations of cohesion over time, cohesion growth trajectories, the fluctuations in within-team variability of cohesion perceptions, or the reciprocal relationships between cohesion and team processes and outcomes, as outlined by Kozlowski [57]; it is difficult to identify how cohesion changes over time. Thus, although cohesion is conceptualised as an emergent state with dynamic properties, few studies have used appropriate measurement methods or study designs to capture these dynamics. As a result, little is known about the underlying mechanisms leading to the emergence and development of cohesion or the mechanisms through which cohesion influences team outcomes [13], [24], [37]. It has been difficult to capture the full picture of the construct. The measurement of cohesion has been at the forefront of issues hindering progress in the field of team cohesion research [29], [37], [40], [42], [100].

2.2.2 Developing unobtrusive behavioural measures of cohesion

Today, researchers are attempting to identify and develop unobtrusive behavioural measures of cohesion in order to measure cohesion longitudinally [29], [37], [40]. Not only will such measures allow for a more comprehensive understanding of cohesion, but unobtrusive behavioural measures will also enable cohesion to be better investigated in teams that operate in fast-paced, dynamic environments (e.g., surgical teams, sport teams, military units) where administering questionnaires may not be feasible [34], [37], [42]. As stated by Kozlowski and Chao [30] "digital traces of meaningful behaviour that are frequent, ongoing, unobtrusive, and process-oriented offer an extraordinary opportunity to gain insights on emergent phenomena and team dynamics". It should be noted that while the goal is to eventually rely on behavioural indicators of cohesion, achieving this goal requires supplementing theoretically linked behavioural indicators with traditional validated cohesion measures (i.e., survey) to assess and ensure construct validity, as per the recommendation by Salas et al. [37].

Although still in its early stages, we are beginning to see an increase in studies leveraging alternative behavioural metrics to investigate cohesion. These include analysis of audio/video recordings of team member interactions [47], [48], [101], [102], leveraging ‘big data’ such as email and social media interactions [43], [44], [103], and analysing the temporal proximity and frequency of face-to-face interaction between team members using ‘sociometric badges’ [45]. For example, Nanninga et al. [47] and Hung and Gatica-Perez [48] analysed non-verbal audio-visual cues and speech features extracted from recordings of team meetings to estimate task cohesion. Using annotations of cohesion from external observers as a reference for evaluating automated methods, Hung and Gatica-Perez [48] found that conversational features such as the total pause time between each person’s speaking turn could accurately estimate high and low levels of cohesion during meetings. Both studies provide early evidence that cohesion could be estimated using audio-visual features extracted from 2- to 5-minute slices of interaction between team members.

Zhang et al. [45] correlated data collected from sociometric badges with self-reported cohesion. The badges were worn around the neck of six team members which recorded their body movement, frequency of interaction, temporal proximity, and speech features. Zhang et al. [46] also collected self-reported perceptions of cohesion and affective state twice a day (once in the morning and once in the evening) for the duration of the four-month simulation of a space exploration mission. They found that the minimum number of face-to-face interactions was the most important feature for estimating both task and social cohesion and that cohesion was correlated with team interaction events. These findings support the notion that cohesion emerges through and is influenced by the interactions between team members. Together, these studies show the value of using unobtrusive behavioural measures of cohesion.

2.2.3 Team communication as a proxy indicator of cohesion

"The ways that individuals talk and write provide windows into their emotional and cognitive worlds" (Pennebaker et al. [104])

Another promising avenue of research is team communication, which has been linked to cohesion in several studies [69], [103], [105], [106]. This thesis will focus on investigating communication as an unobtrusive behavioural indicator of cohesion as a result of findings from Study 1 (Chapter 3). Team communication is defined as "an exchange of information, occurring through both verbal and nonverbal channels, between two or more team members" [107]. Communication has multiple task and social functions: it conveys information, establishes interpersonal/team relationships as well as predictable behaviour and expectations, maintains attention to the task and situational awareness, and is a management tool [69], [108]. Hence, analysing the communication of teams may provide insight into how perceptions like cohesion emerge, develop, and change over time.

One way to investigate communication is through obtaining a frequency count of communication instances. A meta-analysis of 72 studies found that communication in general was positively correlated with cohesion (ρ = .20) [69]. In addition, the relationship was more strongly influenced by a high communication frequency – it was more strongly related to the extent that teams shared information regardless of the distribution of commonly held information compared to the extent that teams shared information that is uniquely held by each member [69]. This finding mirrors the observations from Zhang et al. [45], [46] studies, which together imply that cohesion is influenced by the frequency of interaction, at least to an extent.

Beyond frequency of communication instances, the analysis of communication *content* can also provide an indication of cohesion. Van Swol et al. [109] reviewed the literature on the role of communication content on team functioning through the perspective of the IMOI model. They found that language convergence, which reflects the similarity of sentence structures and vocabulary between speakers, was a key linguistic indicator of cohesiveness (see pg. 16 in Cohesion section for examples) [109]. Language convergence is often measured with a linguistic style matching (LSM) metric used to assess mimicry in language [106]. LSM measures the degree that two or more speakers produce similar rates of 'function words', that is, semantically independent words that form the backbone of language. Function words are derived from the Linguistic Inquiry and Word Count tool [104], [110], a language analysis tool that categorises words into one or more of 80 categories. Examples of such categories include auxiliary verbs (to be, to have), personal pronouns (I, they, we), articles (an, the), and conjunctions (and, but).

For example, Gonzales et al. [106] calculated an LSM group metric from communication generated during 70 student group discussions and correlated it with self-reported cohesion. They found that the LSM group score positively predicted group cohesiveness (b = .28, p < .05) [106]. However, one of the limitations of single word content analysis (as conducted by LIWC) is that it ignores contextual information. Tausczik and Pennebaker [49] caution, "the imprecise measurement of word meaning and psychological states themselves should give pause to anyone who

relies too heavily on accurately detecting people's [or groups] true selves through their use of words" (pg. 30). This may explain why contradictions in word content and cohesion have also been observed – groups with fewer "we" pronouns were more cohesive in Gonzales et al.'s study [106] but an opposite effect was observed in a study on airline crews [111].

Similar to content analysis of single words, communication has also been analysed on a sentence-by-sentence (or full statement) basis [71], [72], [112], [113]. For this type of analysis, communication statements are assigned a behavioural code or category that represents the purpose or function of that statement. For example, the statement "How much time do we have left?" will be assigned to the category "Question". This perspective of using whole sentences versus single words as the unit of analysis was driven by Bales [114], who introduced the Interaction Process Analysis (IPA) coding scheme. The IPA was developed on the assumption that communication statements accomplish either a task function or a socioemotional function. As such, the IPA has twelve categories that fall under two higher-order task and socioemotional categories. The task category is further broken down into questions (3 sub-categories) and answers (3 sub-categories). Similarly, the socioemotional category is broken down into positive sentiments (3 sub-categories) and negative sentiments (3 sub-categories). The IPA has been used in a variety of settings including to investigate communication in digital game clans and social support groups communicate [115]–[117]. Although researchers have since developed their own coding schemes (examples include [52], [118], [119]), the theoretical basis on which the IPA was developed proved an enduring framework on which to analyse team communication.

In addition to frequency counts of words and categories of statements, communication can also be analysed using *sequence analysis*. Communication sequence analysis – which shows the flow of information between members – has been used in the aviation, military, and medical communities [54], [71], [72], [108], [120] (see Figure 8). Using sequence analysis, researchers can identify specific communication sequences that correlate with performance. For instance, a study on multidisciplinary crisis management teams showed that high performing teams

engaged in sequences that reflected collective sensemaking (i.e. 'interpretation' statements followed by other 'interpretation' statements) compared to low performing teams during the decision-making phase [50]. In medical teams, performance[2] was linked to communication sequences where nurses asked clarifying questions in response to commands from physicians [112], [120]. In two studies, Bowers et al. [121] found that high performing military aviation crews were more likely to follow 'leadership statements' (which include commands and task assignment) and 'assertiveness statements' (statements where crew members argued their positions) with acknowledgement and response. The findings by Bowers et al. [121] were important for showing the utility of 'closed-loop communication', that is, the act of confirming or acknowledging a sent message. Closed-loop communication is one of the recommended communication protocols for improving team effectiveness in fast-paced, dynamic teams like medical teams [122]–[124].

The *patterns* of communication sequences also provide insight into how teams communicate, especially under pressure. On one hand, Kanki et al. [72] found that crews communicating in highly predictable ways (as indicated by fewer unique sequences) outperformed teams with highly heterogeneous sequence patterns. Similarly, Stachowski, Kaplan and Waller [51] found that high performing nuclear crisis teams were characterised by fewer, less complex, and shorter communication sequences. On the other hand, Zijlstra et al. [52] study of airline crews only partially replicated these findings. In contrast to Kanki et al. [72], effective crews in Zijlstra et al.'s [52] study did not engage in more predictable sequences or generate fewer unique sequences than less effective crews. Effective crews were, however, characterised by shorter, less complex sequence patterns [52], in line with the observations from Stachowski, Kaplan and Waller [51]

Together these studies indicate that the analysis of communication *sequences* and *patterns* of communication sequences adds incremental value to capturing the

[2] Performance is characterised as the medical institution's accepted best practice. As such, performance was quantified using a measure that assessed the level of agreement of team actions with the respective institutional standards for induction of general anaesthesia. [112]

temporal aspects of team member interactions above and beyond frequency counts of words and communication categories. Importantly, it enables researchers to answer questions on the pattern of information exchange that support effective team functioning. Given the link between communication and cohesion, especially for teams that perform under pressure [54], [103], [125]–[127], team communication may be a potential proxy indicator of cohesion. However, research is required to determine the communication metrics that best capture or reflect cohesion over time. Sequence analysis has also enabled researchers to identify specific communication sequences that correlate with performance. For instance, a study on multidisciplinary crisis management teams showed that high performing teams engaged in sequences that reflected collective sensemaking (i.e. 'interpretation' statements followed by other 'interpretation' statements) compared to low performing teams during the decision-making phase [50]. In medical teams, performance was linked to communication sequences where nurses asked clarifying questions in response to commands from physicians [112], [120]. In two studies, Bowers et al. [71], [121] found that high performing crews were more likely to follow 'leadership statements' (which include commands and task assignment) and 'assertiveness statements' (statements where crew members argued their positions) with acknowledgement and response. The findings by Bowers et al. [121] were important for showing the utility of 'closed-loop communication', which is an act of confirming or acknowledging a sent message. Closed-loop communication is one of the recommended communication protocols for improving team effectiveness in fast-paced, dynamic teams like medical teams [123]. Communication sequence analysis, in general, has been a valuable method for capturing the temporal aspects of team member interactions. Importantly, it enables researchers to answer questions on the pattern of information exchange that support effective team functioning.

2.3 Who does team cohesion matter for?

This thesis focuses on a specific type of team: *swift starting action teams* (STATs). A recent meta-analysis shows that the cohesion-performance relationship is moderated by the level of interdependence in a team such that cohesion is more important when

team tasks are highly interdependent and more complex [39]. As such, this thesis focuses on STATs because they engage in highly interdependent and complex tasks and operate in *extreme environments*[3] [55], [128]. Since STATs operate in high-risk, time-pressured environments, their outcomes critically depend on the team's ability to work together effectively. The way in which STATs form adds to the complexity: teams come together in an ad hoc manner, forming in response to a critical event or task and disbanding once the team has achieved its goal. A STAT is typically composed of members who are unfamiliar (and at times complete strangers) to each other but who fill the necessary roles in the team [129]. STATs include emergency medical teams, ad hoc military units, crisis management teams, and aviation crews [53], [55], [129]. In such teams, poor performance has dire consequences. It should be noted that cohesion-performance relationship has generally been found to be weaker in ad hoc compared to short term or intact teams [39]. Nonetheless, cohesion still influences team functioning in ad hoc teams.

A possible explanation for why the cohesion-performance relationship is weaker in ad hoc compared to short term or intact teams is because cohesion takes time to form in the minds of members and emerge (as depicted in Section 2.1.2). Cohesion is developed through repeated interactions and its influence on performance grows in magnitude over time [30], [41], [57]. This implies that the more repeated interactions team members have with each other, the more likely cohesion is to emerge. For example, a study validating the Group Cohesion Scale-Revised in student groups found that cohesion was more likely to increase in groups who met eight hours each day over a one-week period compared to groups who met once a week for 2.5 hrs over a fourteen-week period [130]. The authors attributed this observation to the increased frequency and sustained interactions demanded by the one-week course. Drawing from Marks et al. [56] proposition of performance episodes, if teams are able to cycle through many performance episodes in a short period of time, it is reasonable to think that cohesion can emerge to a level that is sufficient for influencing performance.

[3] *Extreme environments* are defined as settings where "there are significant task, social, or environmental demands that entail high levels of risk and increased consequences for poor performance". [128]

Questions remain, however, on the rate of performance episode cycles required and relatedly, the minimum amount of time required for cohesion to emerge. For example, Chiocchio and Essiembre [26] argued that teams required at least four weeks of interaction to reach the degree of acquaintance that allows cohesion to emerge. They did not calculate the minimum number of days or weeks in which cohesion has been observed yet they used this argument as the basis of their exclusion criteria for their meta-analysis on the cohesion-performance relationship. This is in contrast to the validation study by Treadwell et al. [130] that observed increased cohesion over a one-week period. It is also in contrast to the recent meta-analysis by Grossman et al. [39] that found significant correlations between cohesion and performance in *ad hoc* teams, although an explicit time period was never defined. The findings from this sample of studies seem to suggest that the intensity of the interactions (i.e., the level of sustained, interdependent interaction) may be more important than simply the frequency that team members meet. Nonetheless, these questions will remain unanswered until behavioural measures of cohesion with a high sampling rate are developed. Given the evidence that cohesion still matters in *ad hoc* teams like STATs (albeit less so compared to short term or intact teams), developing unobtrusive behavioural (proxy) indicators that enable cohesion to be investigated in this context is crucial.

2.4 Could digital games be used as a virtual lab?

In an ideal scenario, cohesion would be investigated with real-world STATs operating ‘in the wild’ – while they are performing work in real-world settings. Unfortunately, there are several challenges present including the complexity of field settings, access to appropriate data, and access to a sufficient sample. Alternative research environments and paradigms such as computational modelling, agent-based simulations, and the use of computer simulations and off-the-shelf (commercial) digital games maybe able to address these issues [57]. For the purposes of this thesis, we will focus on team-based digital games.

There are several advantages to using team-based digital games for research purposes. Team-based digital games afford access to a large sample size compared to conducting research with real-world teams. Given the global popularity of team-based digital games, millions of digital game STATs come together every day to play. Moreover, these games are engaging and immersive, have a pre-existing player community that researchers can tap into for participant recruitment, and participation is not limited to the in-person laboratory, thus expanding participation reach. These games also provide a controlled environment, to an extent. Team-based digital games often have a menu of game modes. While each game mode may have its own unique objective or method of play (i.e., specific maps, rules, or overall gameplay), these remain constant, allowing researchers to observe many different teams operating in the same scenario. Take for example 'Summoner's Rift', the classic mode in *League of Legends* [68]. In this mode, the objective of the game is to destroy the enemy's base. In the process of achieving the main objective, teams have the option to complete several sub-objectives. The objective of the game remains constant but the process in which teams achieve the objective is variable. This allows researchers to investigate differences in the mechanisms and boundary conditions linking team inputs to outputs. In contrast, emergency medical teams or military units may face a variety of different and unpredictable scenarios, which adds greater complexity to the factors that researchers have to control for. By controlling the scenarios in which teams operate, researchers are able to isolate the human factors that contribute to success.

Team-based games, especially competitive games, mimic the task and teamwork demands of real-world STATs. These games are challenging, complex, and highly interdependent, with a growing body of research noting the similarities between the virtual and physical team environments [58], [63]. Eaton et al. [58], [131] drew parallels between the team characteristics, environment, and task and teamwork demands of military STATs and *League of Legends* [68] teams. The authors noted that military combat units are often composed of 4-5 soldiers with clearly defined roles, but members may vary on their familiarity and prior work history together, similar to the *League of Legends* [68] team structure. Military combat units are also required to adapt – to respond rapidly and effectively in light of an ever-changing environment,

again, similar to the challenges that League of Legends teams face. On the other hand, Cooke et al. [60] found that teams composed of members who played *Counter Strike: Global Offensive* (CS:GO) [132] together performed better in a novel uninhabited aerial vehicle (UAV) task compared to teams of flight students with no CS:GO experience and attributed the difference to transfer of command-and-control experience gained through playing CS:GO. Cooke et al. [60], however, did acknowledge that a lack of work history may have been a confounding factor, although they were unable to determine its effect on performance.

Adjacent to these studies is the research conducted by Toups et al. [59] who demonstrated how training on a game that taught coordination and communication effectiveness improved coordination and communication processes in fire emergency response (FER) teams. Despite the game's low physical fidelity (i.e., the game did not replicate the visual appearance of the firefighting environment), it led teams to improve their real-world performance on simulated firefighting tasks. The game's effectiveness was attributed to how closely it matched task and teamwork demands that FER teams faced. The findings from Toups et al. [59] provide further support for digital games as valuable research tools when the team demands match those in the real-world environment. Importantly, these studies indicate that digital games are a naturalistic team environment in which to study teamwork.

Using digital games for research purposes has its limitations. Digital games are not designed with scientific theory or research in mind. As such, Kozlowski [57] and Santoro et al. [29], encourage researchers to carefully consider whether the research environment, in this case the game design, would fit the phenomenon of interest such that the phenomena can be measured with appropriate resolution. In addition, behavioural metrics of interest may not be recorded. One of the ways that researchers collect in-game behavioural metrics is through publicly accessible Application Programming Interfaces (API) provided by the game developers. Although it is easier to collect a large sample of data, researchers are reliant on the data access methods that are exposed in the API. A potential solution to this problem is through direct collaboration between researchers and game companies. Through this partnership,

researchers can gain access to data that is not publicly available and can help game companies identify metrics that are inherently useful for research. This solution may, however, be hindered by game companies' business needs and their willingness to share non-publicly available in-game behavioural metrics. A second solution, which is the approach that this thesis takes, is to supplement in-game behavioural metrics with more traditional methods such as observation, video coding, and/or questionnaires. Although laborious, this method allows researchers to directly collect relevant, theoretically linked metrics.

In addition, teams in digital games are not faced with the same stakes as real-world teams. Digital games are developed for entertainment purposes. While digital game STATs may face similar challenges as real-world STATs (i.e., performing in a time-pressured environment, typically working with unfamiliar members, and engaging in complex and highly interdependent tasks), the consequence of poor teamwork is much more critical in real-world STATs. This raises questions on whether digital game STATs will strive towards effective team functioning. We believe they will for several reasons. Players recognise the importance of collaboration for succeeding. In their qualitative investigation on how players collaborate effectively with strangers in *League of Legends,* Kou and Gui note: “Players agree that collaboration outweighs individual skill” [64]. The motivation to perform well is also reflected in the growing body of literature investigating success factors in competitive team-based digital games, especially those relating to team factors [133]–[135]. Team success has been investigated through a compositional lens such as playstyle or character composition [136], [137]. While others investigated the influence of one player on another with the goal of recommending teammates that improve players skills and performance [138], [139]. Together, these studies suggest that effective teamwork is recognised as important, and that researchers and players alike are constantly looking for factors that improve team success. In general, the advantages of digital games far outweigh its limitations, making it an attractive research paradigm to address issues and open questions in team research.

2.5 Conclusion

In summary, cohesion is important to team success, and may be particularly important for STATs. Until now, it has been difficult to investigate cohesion in STATs because of measurement limitations and the complexity of field settings. In particular, a heavy reliance on survey measures and lack of longitudinal data collection have led to gaps in knowledge of the antecedents of cohesion, the influence of cohesion at different stages of team development, and the boundary conditions that influence cohesion emergence and development. However, the advent of sophisticated, complex, competitive team-based digital games has created an alternative avenue to unobtrusively collective, observe, and analyse behavioural indicators of cohesion. The remainder of this thesis will focus on identifying and validating potential behavioural indicators of cohesion, specifically within (ad hoc) digital game STATs.

Chapter 3: Identifying potential behavioural indicators of cohesion in ad hoc digital game teams

To begin the investigation of unobtrusive behavioural indicators of cohesion in ad hoc teams in digital games, I conducted a qualitative investigation of factors that influence players' intention to return to a team after the first encounter. As mentioned in Chapter 1, cohesion definitions centre around two key notions: (1) that cohesion reflects some form of bond or attraction – driven by either the team's tasks and/or the relationship with team members, and (2) that this bond or attraction inspires continued commitment/causes a team to remain together. As such, the intention to return to or remain in a team can indicate team cohesion.

In this study, we interviewed 14 gamers on instances when they have added a stranger to their Friend List after a first encounter. The findings suggest that there are multiple task and social factors that influence players' decision to add a stranger, and these factors primarily manifest through communication. The findings imply that investigating team communication may provide insight into how bonds form between team members and give rise to cohesion.

3.1 Abstract

A by-product of cohesion is the intention to return or remain in a team. In digital games, anecdotal and empirical evidence shows that players form friendships with strangers in ad hoc competitive teams, indicating that players develop intentions to return or remain in a team. This suggests that some level of cohesion forms between strangers after a first encounter in ad hoc teams. This study investigates that factors that influence a player's intention for repeated play with a stranger in competitive ad hoc teams. 14 players were interviewed on their experience in ad hoc competitive team-based games. The data were thematically analysed and four main themes were identified: (1) unexpected bonds with strangers, (2) evaluation based on task factors, (3) evaluation based on socio-emotional factors, and (4) the mediating effect of the communication medium. The findings suggest that behaviours that strangers are evaluated on primarily manifest through team communication. The findings imply that the interactions between players can be used as an indicator of team cohesion in ad hoc teams.

3.2 Introduction

Cohesion is a desirable because it influences the longevity of a team -- the intention to remain or return to the team is a well-known by product of cohesion [3], [19], [140]. For example, in a study of 25 teams consisting of 360 amateur and professional players from various sports (e.g. volleyball, basketball, handball, football, and water polo), Onağ and Tepeci [19] found that team cohesion accounted for 11% of the variance in reported intention to remain in the team. Similarly, a study of 2306 volunteers in the Australian emergency services [3] found that volunteers who perceived higher cohesion felt less inclined to leave their job (cohesion-intention to leave : r = -0.37). Research on military recruits shows a similar trend. An early meta-analysis of cohesion in military units [25] (33 samples and composite samples) found a small positive correlation between team cohesion and personnel retention, r = 0.22. This effect size was also observed in a study of 714 Canadian Army personnel (cohesion-intention to leave: r = -0.28) [141].

Cohesion is not only linked to the *intention* to remain in a team but extends to the *actual behaviour* of returning or remaining in a team. This is corroborated by findings from various studies by Spink and colleagues [1], [2], [142], [143] investigating the influence of cohesion on both the intent and actual behaviour of returning to the team in athletes from various sports. For example, Spink et al. [2] investigated 22 ice hockey players on eight teams and found that perceptions of cohesion accounted for 16% of the variance in actual return to the team. It should be noted that this relationship was strongly driven by perceptions of task cohesion (rather than the social dimension or combined task and social dimensions) such that players who returned to play in the following season had significantly higher perceptions of task cohesion. Together, these studies suggest that the intention to return to a team is a by-product of cohesion. People are more likely to return to teams that they perceive as cohesive. Thus, the intention to return to a team can be used as a proxy indicator of cohesion.

In ad hoc teams within competitive team-based digital games, players typically play with strangers. If players want to play with their teammate again, they can usually either send a 'Friend Request', which adds the stranger to their friend list, or they can invite the stranger to their next immediate game. There are few other mechanisms that allow players to make it known that they want to remain in the same team or with the same teammate. From here on, we will use the phrase 'intention for repeated play' when referring to a player sending a friend request or inviting a stranger to the next immediate match. Since these behaviours indicate intention to remain in the team, it suggests there was likely some sense of cohesion in the first encounter. It should be noted, however, that since this relationship is derived from investigations of non-digital game teams, there may be additional complexities to this relationship that have yet to be uncovered. Nonetheless, given the theoretical underpinnings of cohesion as an affective state that inspires a tendency to remain in the team [74], [144], it is reasonable to assume that intention for repeated play in digital games is, at least in part, influenced by perceptions of cohesion.

In games research, a large body of work has been conducted on how new relationships between players form [145]–[150]. However, the majority of work in this domain has focused on interactions and social relationships within guilds [151] and third-party group-finding platforms [152]–[155]. Few studies have investigated friendship formation in ad hoc teams within competitive team-based games, which do not share the same social structures. While guilds and third-party group-finding platforms provide a platform for prolonged and ongoing interactions between strangers, the interactions with strangers in many competitive games are short (match duration of ~30 minutes) on-off encounters with little chance of organic future interaction (due to the matchmaking systems).

Based on theories of relationships formation [156]–[158] the social structure in competitive team-based games is not conducive for relationships to develop organically. Relationships usually develop as people become familiar with each other through repeat encounters that occur over time [159], [160]. In team-based video games, organic repeat encounters are unlikely [161]. For example, a study on players in *Halo:Reach* [162] found that strangers typically played one game together whereas friends played an average of ten to thirteen consecutive games [163]. Nonetheless, there is growing empirical and anecdotal evidence that players form relationships with strangers in competitive team-based games despite the short, one-off encounters in ad hoc teams [150], [164]–[166]. In their qualitative investigation of team formation in esports, Freeman and Wohn [164] noted that amateur players leveraged a game's matchmaking system to find future teammates, although they did not uncover what factors influenced their decision to develop future relationships with strangers. In a similar vein, Vella et al. [165] interviewed 15 players and investigated the factors that led players to form friendships with others, among other topics. Their investigation highlighted the importance of trust in developing relationships which arose from repeated encounters over time while using voice communication. Like Freeman and Wohn's study, Vella et al. [165], however, the authors did not explicitly uncover the behaviours that inspired the initial formation of the relationship between strangers. As such, one of the contributions of the present study in this chapter is investigating the

behaviours that strangers exhibit which give rise to the first instance of intention for repeated play.

This study also contributes to the wider body of cohesion research, especially within digital games. With the exception of studies from Buchan and Taylor [167] and Hudson and Cairns [168], there are relatively few studies investigating team cohesion in digital games. Hudson and Cairns [168], [169] developed a measure of cooperative social presence which they termed 'cohesion'. Their findings suggest that cohesion (based on their conceptualisation) was correlated with match outcome in the game *Dota 2*. Upon closer inspection of the development of the measure, it was apparent that the 'cohesion' dimension included other factors, such as trust and theory of mind, which are related constructs but distinct from how cohesion is conceptualised in the wider team literature. Nonetheless, it suggests that cohesion is a potential influential factor for performance in competitive team based games. Buchan and Taylor [167] conducted a qualitative study investigating factors affecting cohesion in teams of the Multiplayer Online Battle Arena (MOBA) genre, one of the competitive team-based game genres: games include *League of Legends* [68]*, Dota 2* [170]*,* and *Heroes of the Storm* [171]. Twelve participants (11 male, 1 female) were interviewed. Buchan and Taylor [167] identified five factors that contributed to team cohesion: how much players communicate (Team Communication), whether players played with friends or strangers (Friends or Strangers), how well players perform relative to their teammates (Level of Play), the composition of roles and responsibilities in the team (Team Composition), and the extent that players have a positive or negative outlook on the game (Psychological State). These findings have been insightful in providing an initial theoretical model of factors that might influence cohesion in competitive games.

However, since the authors approached the investigation from the perspective of both 'optimal team play' and cohesion, it is unclear how the factors uncovered in Buchan and Taylor's [167] investigation relate to either or both of these constructs. Furthermore, the findings relate more to the contextual factors that increase the likelihood of cohesion developing. It is perhaps more valuable to understand the *behaviours* that strangers exhibit that give rise to perceptions of cohesion. If we

identify the behaviours that give rise to cohesion, we can then design environments or behavioural nudges that prompt players to engage in cohesion-building behaviours.

Therefore, the present study closely follows the work of Buchan and Taylor [167] but differentiates itself by focusing on investigating behavioural factors that strangers exhibit during a match. In addition, we explicitly use intention for repeated as a metric for cohesion. We also include other competitive genres such as First Person Shooter games (i.e. *Overwatch, Apex Legends*) in addition to games in the MOBA genre. In doing so, we can begin to identify behaviours that inspire intention for repeated play in ad hoc teams in competitive digital games, which can thus be used as proxy indicators of cohesion.

3.2.1 Research Question

The aim of this research is to investigate factors that influence cohesion in ad hoc teams in competitive digital games. To do so we investigate factors that influence players to send a friend request after a match has ended. Since the intention to return to a team is a by-product of cohesion, taking this approach allows us to identify potential antecedents of cohesion in ad hoc teams in competitive digital games.

> **RQ1:** In ad hoc teams of strangers, what factors influence players' intention for repeated play with a stranger (either through sending a Friend Request or inviting a stranger to the next game) after the first encounter?

3.3 Methods

3.3.1 Participants

Participants were recruited from the University of York through flyers and online through *Reddit*. Participants were included in the study if they were non-professional players, at least 18 years of age, and regularly played a competitive team-based game in ad hoc teams. 14 participants were recruited based on these criteria (4 identified as female, 9 identified as male, and 1 identified as non-binary). Some of the competitive team-based games that participants regularly played include *League of Legends, Dota*

2, Overwatch, Counter-Strike Global Offensive and *Rainbow Six Siege.* Participants were aged between 18 and 30 years old.

3.3.2 Interview Question Design

The goal of this study was to identify factors that spontaneously converted a first encounter between teammates who are strangers into a second encounter, regardless of the relationship it became. The questions were designed based on the theoretical correlates of cohesion combined with my experiences of ad hoc teams in competitive team-based games. The initial interview set included questions on:

- Player motivation
- Frequency of playing with pre-existing friends
- The number of friends that players could regularly play with
- Typical communication channels
- The perceived effect of game mechanics and structure on team communication
- Players' experience with teammates who were strangers
- Players' experience befriending strangers
- Situations that encourage more interaction with strangers

The interview questions were refined throughout the study as the theory started to develop. A selection of the most relevant questions is found in Table 1.

Table 1 Interview questions for player's experience with strangers.

	Interview Questions
1.	How do you typically communicate in these games?
2.	Are there different communication norms between games/genres?
3.	How much opportunity and time is there to talk about things outside the in-game objectives?
4.	If you have ever befriended a stranger after a match, how did that happen?
5.	What makes a positive experience when playing with strangers?

6. Are there different situations that make it more or less likely to enter into voice chat with strangers?
7. What is the main difference when playing with friends compared to playing with strangers?

3.3.4 Procedure

Semi-structured interviews were conducted. Each interview was approximately 30 minutes. The interviews were conducted in-person and online via *Discord* [172]. At the start of the interview, participants were briefed on the interview procedure and provided informed consent. Participants were informed of their right to withdraw at any point of the study with no repercussions. During the interview, participants were asked questions relating to their experience playing with strangers, the perceived effect of game design and game features on their interaction with strangers, and the difference in experience between playing with strangers compared to playing with friends. At the end of the interview, participants were thanked for their time.

3.3.5 Data Analysis

We conducted an inductive thematic analysis following Braun and Clarke [173]. The objective of the thematic analysis was to identify themes in players' intention for repeated play after a first encounter with a stranger in competitive team-based games. The themes that emerged from the data suggests that players' intention for repeated play is influenced by their expectations when entering a match with strangers, their behaviours that strangers exhibit, and the communication medium.

3.4 Results

3.4.1 Factors that influence intention for repeated play

The findings suggest that players are constantly evaluating their teammates when they enter a match with strangers in an ad hoc team. The evaluations seem to occur subconsciously, without active effort from players. Evaluations fall into two

categories: task-related evaluations and social-emotional evaluations. Task-related evaluations are evaluations of player behaviour that contributes to the team's ability to achieve its objective. These behaviours include (1) being communicative and responsive, (2) providing encouraging and positive communication in the face of adversity, (3) responding positively to and providing constructive feedback, and (4) exhibiting skill and competence in their role. On the other hand, social-emotional evaluations are evaluations on less overt characteristics like (1) sense of humour, (2) general interest, and (3) values. These factors signal social compatibility and influence interpersonal attraction. However, the extent to which that players can make social-emotional evaluations depend on the features of a game. The main game feature that influences evaluations of social-emotional factors is the communication medium. Findings from participant interviews suggest that games where voice communication is the norm are more likely to support social-emotional evaluations compared to games where voice communication is not the norm. The findings also suggests that it is not necessary for a player to make positive evaluations on *both* task-related and social-emotional factors for them to add a stranger to their friend list. The presence of positive evaluations on both evaluation categories is not required.

3.4.2 Theme: Unexpected bonds with strangers

The findings suggest that players do not enter a match with the explicit intention of forming bonds or finding someone to add to their friend list. Players describe "running into" or "finding themselves" unexpectedly connecting with teammates who are strangers. Players do not expect to end a match with the intention for repeated play with strangers.

> *We had some games where basically we would run into a couple of people who were being communicative and seemed nice in the voice chat. We thought, "Okay we'll add each other and stick together for a bit and play some games together". [P8, Non-binary, 26 Overwatch]*

> *If you're solo queuing, well there's no one that you already have a link to muck about with so it's almost like "OK I'm here to play the game". Sometimes you'll play and you'll find yourself developing a little bond with someone else and then you'll muck about with them and then those bonds form. And then you're like "Hey, add me friend". [P9, Male, 21, Rainbow Six Siege]*

In fact, players expect to have minimal communication with strangers on their team, and some even expect to be met with silence. In other words, players do not necessarily expect teamwork to occur when playing with strangers despite playing team-based games; a finding that was also found by Tyack and colleagues [2016]. Thus, when players form bonds with strangers in their team and add them to their friend list, this occurs spontaneously.

> *When I solo queue, I usually expect that it's going to be like flipping a coin. I expect that I can either get a team full of silent people that don't listen and just do their own thing... and it's frustrating or I can get a team of people that, you know, decide to actually communicate. [P12, Male, 18, Overwatch]*

3.4.3 Theme: Evaluation based on task-related factors

When players enter into a match with a team of strangers they subconsciously evaluate their teammates' ability to accomplish team goals (task-related factors). Task-related factors that are evaluated are:

1) being communicative and responsive
2) providing encouraging and positive communication in the face of adversity
3) responding positively to and providing constructive feedback
4) exhibiting skill and competence in their role

These factors are behaviours that signal a willingness to engage in teamwork, apart from 'skill and competence'. Given that players do not enter matches with the expectation of teamwork and collaboration, strangers who signal a willingness to engage in teamwork behaviours are generally perceived more positively than strangers who do not.

Being communicative and responsive.

Strangers who are communicative and responsive to communication tend to stand out. This may be attributed to the perception that teamwork is unlikely to occur with strangers. Strangers who are communicative and responsive enable the team to coordinate actions, increasing the team's chance of success.

> *... you kind of just expect that they're not going to listen. But there was a dude that responded... I was like "Heyyy". I was already playing in a group with one or two friends and we were communicating and the fact that this other guy in the group was communicating meant that... For the most part the team was communicating and we kind of rolled over everyone else. So we were like "Come join the group man". So then he joined, we talked and added him on my Friend List and we got talking a bit more. [P9, Male, 21, Rainbow Six Siege]*

> *In a competitive game like Overwatch, yeah it's [communication on voice chat] pretty much a means to an end. It's if you communicate effectively then you're more likely to win. [P8, Non-Binary, 26, Overwatch]*

When a stranger is being communicative and responsive, it signals that they are committed to achieving the team's objective (i.e., winning). As such, strangers are evaluated positively. Interestingly, winning does not seem to be a prerequisite for repeated play. While participants state that having a communicative teammate increases their chances of winning, intention for repeated play seems to depend more strongly on whether the stranger engages in teamwork behaviours like being communicative and responsive to communication.

> *That usually is a very positive experience when people actually try to communicate and win. You know, that's when you usually meet people that you might wanna play with again. [P12, Male, 18, Overwatch]*

In contrast, a stranger who is not communicative or responsive can frustrate players, leading to negative evaluations.

> *Occasionally, you'd get a random [stranger] who wouldn't use the voice chat and they'd only use the text, which used to be really annoying, because. . . We had this one guy one time who uh. . . he just wouldn't respond to anything. [P6, Female, 28, Guns of Icarus]*

Thus, a stranger who is communicative and responsive to communication is evaluated positively, which in turn influences the likelihood of intention for repeated play.

Providing encouraging and positive communication in the face of adversity. Strangers are also positively evaluated when they keep a positive attitude in the face of adversity. This manifests in the form of encouragement and positive sentiment.

> *I like when people are super positive even if things aren't going well. [P13, Female, 18, Overwatch]*

The short duration of matches, high level of competition and the necessity of effective teamwork for success can create a stressful environment for players [174]. Teams are small with 5-6 players per team depending on the game. In addition, each player on the team typically has a role which complements the other roles on the team. These factors create an environment where the impact of poor performance at the individual- and team-level is severely felt. In other words, negative feelings from setbacks in a match, such as dying to an enemy or failing to secure an objective, are amplified.

> *[…] people getting very angry because... you're stuck in a game with these people. If they mess up it means that it's really bad for you in a way that it isn't true in other games. In a MOBA, they [the enemy team] get advantages that make them stronger from your teammates playing badly, which means that...*

> *[poor performance and poor teamwork] is ruining your time more directly. [P4, Male, 26, Dota 2]*

As a result of the amplified negative feelings, strangers may engage in blaming and verbal aggression (termed 'toxic behaviour') [175]. This further deteriorates team performance[176]–[178] and creates a negative experience for their teammates.

> *It was a problem with their attitude really [when referring to strangers]. They would blame everything else that wasn't them basically. And they would get really kind of angry and frustrated. They just weren't that fun to play with. [P8, Non-Binary, 26, Overwatch]*

Toxic behaviour in light of setbacks are prevalent in ad hoc teams of strangers and players seem to anticipate such behaviour when playing with strangers. Combined with the challenge of coordinating with strangers, this creates a situation where players enter into a match with an ad hoc team of strangers with some expectation of a negative experience.

> *Obviously with a team game if you're playing with strangers, it's more difficult to coordinate people. They tend to be more toxic and its a less pleasant experience. [P10, Female, 27, Dota 2]*

Strangers who exhibit toxic behaviour in light of setbacks are negatively evaluated and players are less likely to want to play with these strangers again. In contrast, strangers who keep a positive outlook, expressed through encouragement and morale-building, are positively evaluated.

> *It's praising either your efforts or they'll say to the team "Alright guys, nice try that round. It's okay that we didn't win but we've got this next one". [P15, Female, 18, Overwatch]*

Strangers who continue to be team-oriented via engaging in behaviours that benefit the team, even when their own individual performance is poor, are also positively evaluated.

> *People who want to work together and who have that higher level view of the game… [they might say] 'Okay, this might suck for me but if I do this thing, it will benefit the team and that's good for everyone.' [P10, Female, 27, Dota 2]*

It seems that a positive attitude in the face of adversity, expressed through encouragement, morale-building communication, and continued engagement in team-oriented behaviours, leads to positive evaluations. On the other hand, a negative attitude in the face of adversity, expressed through blaming and verbal aggression, leads to negative evaluations. However, the impact of a negative attitude on intention for repeated play seems to be stronger than the impact of a positive attitude. This is evidenced by how the anticipation of potential toxic behaviour when playing with strangers puts off some players from playing with strangers completely. It suggests that while a positive attitude in strangers may increase the likelihood of intention for repeated play, a negative attitude completely erodes any chance of intention for repeated play.

> *If you think about the kind of games that I'm playing like League of Legends and Counter Strike... They're competitive games and that brings out the toxicity in people… I'm too chill and laid back for that. I don't want someone telling me that I'm bad at the game. [P3, Male, 23, Various]*

Responding positively to and providing constructive feedback.

Strangers are also evaluated on how they provide and respond to constructive feedback. Feedback is often given unsolicited. It is not uncommon for players to receive feedback on their performance, progress, or decisions from teammates but this is not always given constructively.

> *Sometimes people are just like "Oh you're shit" or whatever. And I'm like "Yeah okay I did play a bit shit there" but that's not like feedback that I can follow really. [P4, Male, 26, Dota 2]*

> *I think deep down I just appreciate when somebody says, "Hey I don't think you should be playing this character because of these reasons". If they just say "Don't play because you're bad or because this character is really bad" then I don't really know what to do with that comment. [P5, Male, 23, Overwatch]*

On the other hand, when players give feedback to a stranger, it can be interpreted wrongly or received negatively. Strangers may respond defensively if they interpret a helpful comment as a personal critique.

> *When you try to point out things they could do to potentially help them not play as aggressive or improve their gameplay to any degree, they get incredibly defensive. [P11, Male, 20, League of Legends]*

> *For instance, there was this one guy playing middle lane and as soon as he died he started blaming me and a couple other players for not doing some things and then I just said something like "Why don't you try doing this" and then the guy started flaming me and started becoming quite aggressive. [P5, Male, 23, League of Legends]*

When strangers provide unconstructive criticism or respond negatively to feedback, it is possibly an expression of frustration. This is because feedback more likely occurs when something has gone wrong. Thus, feedback seems to be given in a reactive rather than prescriptive manner.

> *I think people are normally quite focused on what they are doing so it's pretty rare that like... They'll be like "Oh I'm going to look at what item [my teammate has]..." It's normally after the fight that this stuff happens. It's normally after they've seen what you've done. It feels like often that sort of thing comes up*

> *when things have gone badly, and they're just like "Oh why did you do this. That was obviously stupid". [P4, Male, 26, Dota 2]*

This implies that strangers are likely experiencing negative emotions and thus may give negatively-charged feedback. Similarly, if strangers are in a bad mood because of a negative game event, feedback will be interpreted through a negatively-charged lens. The way in which feedback is communicated becomes extremely important.

> *If people feel like you're criticising them they'll respond really badly and just flame you when actually you're just trying to be helpful. . . if you can make a suggestion to someone and either they react neutrally or like positively then it makes for a really nice experience in the game. [P10, Female, 27, Dota 2]*

Strangers who are able to provide and receive constructive feedback in a positive manner may signal that they are team-oriented. Strangers who exhibit these behaviours are evaluated positively, which in turn increases the likelihood of intention for repeated play.

Exhibiting skill and competence in their role.

Finally, strangers are evaluated on their skill and competence. While it does not explicitly signal a willingness to engage in teamwork, it is an important marker of their ability to be an effective teammate in future matches.

> *He was a bit better at the game than us so he carried us in the game... maybe that predisposed us to join his company, I don't know but that could be a factor [for why the stranger was invited for repeated play]. [P4, Male, 26, Dota 2]*

Exhibiting skill and competence is important because it impacts the outcome of the match. Since the outcome of a match directly affects a player's progress in the game, strangers who are skilled and competent in their role are evaluated positively. The instrumental benefit of having a skilled and competent teammate influences intention for repeated play.

> *I end up adding or getting added generally because a game goes well. And if you're the reason for it or a teammate is the reason for it, you tend to add each other. [P11, Male, 20, League of Legends]*

These findings indicate that the intention for repeated play is influenced by positive evaluations on task-related factors such as being communicative and responsive, providing encouragement and remaining positive in the face of adversity, responding positively to and providing constructive feedback, and exhibiting skill and competence. These factors signal that a stranger is not only effective in their role (via skill and competence) but that they are willing to cooperate, coordinate, and collaborate with the team to achieve team objectives. Clearly, these factors contribute to perception of task cohesion. Importantly, it seems that strangers stand out when they exhibit these positive task-related behaviours because players do not anticipate effective teamwork or to encounter team players when playing in an ad hoc team of strangers. Therefore, when players encounter competent, team-oriented strangers, it inspires intention for repeated play.

3.4.4 Theme: Evaluation based on social-emotional factors

Intention for repeated play can also be influenced by a positive evaluation on social-emotional factors. These factors are typically less overt and do not necessarily emerge in every match. They are also not directly related to the match, the game, or the immediate task at hand. Social-emotional factors that players evaluate strangers on include:

1) shared sense of humour
2) shared general interest
3) shared values

It should be noted that the type of game influences the opportunity for social-emotional factors to manifest in a match. The moderating effect of the game will be described in Section 3.4.5. If the game allows social-emotional factors to manifest

easily, intention for repeated play will likely be influenced by a combination of task- and social-emotional factors.

Social-emotional factors contribute to how enjoyable the game experience with the stranger is, beyond gameplay. In other words, even if players were playing a different game or doing a different activity altogether, a positive experience emerges as a result of their social compatibility. Hence, intention for repeated play is more likely if a player is socially compatible with a stranger.

Shared sense of humour

One of the social-emotional factors frequently associated with intention for repeated play is having a shared sense of humour. Being able to laugh in a match adds an additional layer of enjoyment. Moreover, humour is useful for diffusing tension in a game and keeping up the morale in the team, which in turn creates an overall positive experience when playing with strangers.

> *If everything is super serious but then there's one guy who's playing serious as well but he just keeps making like fire jokes the whole time, that's a good experience because it really helps with the morale of everyone else and it sort of lightens things up. . . I think humour is definitely a really important part of being able to find positive online social experiences in video games. [P7, Male, 25, Overwatch]*

However, simply expressing humorous remarks does not necessarily influence intention for repeated play. It is important that humour is *shared.* Players are more likely to add strangers to their friend list who have a similar sense of humour to themselves.

> *Not everybody has the same sense of humour... when I meet someone with a similar sense of humour to mine, we can get along and make jokes about what's happening. I think that's, for me personally at least, that's what makes me want to add someone [P14, Female, 24, Overwatch]*

> *He just sort of gelled well socially, you know. He was nice, he's also a bit funny… He's just sort of fit with the group in terms of like finding similar things funny, being broadly speaking, nice [P4, Male, 26, Dota 2]*

On the other hand, if players encounter strangers who do not have a similar sense of humour, these strangers are viewed as socially *in*compatible. In these instances, repeated play is unlikely.

> *Occasionally you'll get someone [who] join[s] voice chat and they'll make a racist joke or sexist joke and you'll go "Ooh (in disgust) okay... We're not really similar people". [P10, Female, 27, Dota 2]*

Considering the subjectivity of humour, a shared sense of humour may also signal deeper similarities in attitudes and values. Jokes are encrypted with implicit background knowledge [179]. It can be argued that those who 'get' the joke share the same background knowledge, which might give rise to feelings of similarity, affiliation, and rapport. A shared sense of humour, therefore, influences intention for repeated play because it indicates some level of social compatibility. When a stranger is thought to be a good team player, competent, and is socially compatible via their shared sense of humour, the likelihood of intention for repeated play increases.

> *If there's synergy with that [sense of humour] and if we play well together and they're not being toxic, I'll usually send them the friend request. [P7, Male, 25, Overwatch]*

Shared general interests

Having shared general interests also influences intention for repeated play. Similar to shared humour, being able to talk about topics external to the game signals social

compatibility. Indeed, players express that having conversations while simultaneously playing the game can make the immediate game experience more positive.

> *I think I get more positive experiences out of the fact that I'm having a social experience… Like you know, playing with people where we're having a laugh and telling stories and playing the game at the same time, that's a more positive experience than actually if all the talk was focused on that game. [P1, Male, 30, Counter-Strike]*

> *For me, just having people who will talk to me, I guess, outside of just telling me what objectives to do. [P14, Female, 24, Overwatch]*

Players will have a positive evaluation of strangers with common interests. As a result, players are more likely to add such strangers to their friend list.

> *If you end up hitting it off for chatting shit, you end up friending them and just decide to keep playing away I guess [P11, Male, 20, Overwatch]*

Similar values

Having similar values can also influence intention for repeated play. The term 'values' here is used to refer to the level of importance that players place on different experiences of the game. In this sample, there are three different experiences that players value to different extents: teamwork regardless of match outcome, the social experience of playing with others, and winning via skill and competence. For players who value teamwork regardless of the match outcome, good sportsmanship with strangers contributes to a positive experience.

> *People that know nothing about one another and will most likely never see one another again, for this very brief moment in time they've come together and they've tried their best to just beat one another and be like good teammates with their own team. I just think that's really nice. That idea alone is really nice. [P5, Male, 23, Overwatch]*

Positive experiences seem to arise from teamwork regardless of the match outcome because players do not inherently expect teamwork to occur. This is despite the fact that a team's best chance of winning a match is through teamwork.

> *Often times in games, teams won't communicate or you'll have this one guy that's trying to say something to the team and they're not listening but every now and then there will be games where someone starts talking, someone starts, you know, also responding to that and suddenly you have a whole team that's actually working together and it's beautiful to be honest [P9, Male, 21, Rainbow Six Siege].*

On the other hand, some players are not very competitive and view competitive team-based games as a social experience with others. For these players, having a positive social experience, regardless of the game outcome, has more value than winning itself.

> *Just friendly people, regardless of whether they're on my team or not. If people are out there to have a good time and they're not so... For me at least, not so heavily focused on winning. [P3, Male, 23, Counter Strike and League of Legends].*

In contrast, players who place a high value on winning seem to more strongly evaluate strangers based on their skill and competence. For these players, factors such as friendliness or humour are not as highly valued.

> *Rather than being um... Nice. Just purely based on the skill of the player. [...] So if someone was cracking jokes I'd probably just ignore them? [P2, Male, 23, League of Legends]*

The presence of different values suggest that there can be tension between players when values are not shared. One can imagine that players who value winning above

other experiences might become more frustrated with their teammates who do not exhibit the same zeal in wanting to win the game. This frustration might be expressed as verbal aggression or other negative behaviour. For the player who places less importance on winning, the behaviour of the frustrated player would ruin their experience. Thus, given that players have different values, strangers are evaluated more positively if they share similar values with the player. As such, having similar values can influence intention for repeated play through signalling social compatibility.

In summary, this subsection described the task-related and social-emotional factors that strangers are subconsciously evaluated on. Positive evaluations on these factors increase the likelihood of intention for repeated play. However, the findings suggest that evaluations on *both* types of factors is not necessary for an intention for repeated play to emerge.

3.4.5 Theme: Moderating effect of communication medium

The extent that players can make evaluations on social-emotional factors depends on the communication medium that strangers use. Different games provide different communication tools and have different communication norms. Common communication tools include pings, automated (text and audio) messages, text chat, voice chat, and annotations [180], [181]; a description of these communication tools can be found in Table 2. These tools are differently available depending on the game. Games in the FPS genre such as *Counter Strike: Global Offensive (CS:GO)* [132], *Overwatch* [182], and *Valorant* [183] allow in-game voice communication in ad hoc teams. In the Multiplayer Online Battle Arena (MOBA) genre, not all games support in-game voice communication. For example, *Dota 2* allows in-game voice communication in ad hoc teams, whereas *League of Legends* only supports in-game voice communication in premade teams.

Table 2 Common communication tools in team-based games.

Communication Tool	Description

Pings	Temporary attention-focusing cues. Pings can be semantically imbued (e.g., a question mark that signals 'enemy missing') or non-semantically imbued (e.g., a blue circle that blinks).
Text chat	Text messages that can be sent to teammates (i.e., allied chat) or all players (i.e., all chat)sss
Voice chat	Voice communication between players. Players can either 'push-to-talk' or be on voice communication throughout the match.
Automated text/voice messages	Pre-set phrases that are displayed as text chat or 'spoken' by the character.
Emotes	Expressive images or character animations that are used to express emotions.
Annotation	Free hand annotations that players can draw on the mini map to signal more detailed gestures to teammates

Of all the different communication norms, games that afford voice communication provide the most opportunity for evaluations of social-emotional factors. Voice communication allows a higher volume of information to be conveyed at a time. Unlike typing, which occupies your hands, voice communication does not interfere with game controls. A player's hands are used to control their character, use abilities, and to interact with the environment. Therefore, when players type text messages, it interferes with their progress in the game. This creates a situation where text chat is seldomly used for conversations unrelated to the task at hand.

> *You can't really chat about stuff in the [text] chat. You barely use the chat as it is to talk about in-game stuff so chatting about external game stuff in the chat is a lot. It's too hard. The game is way too fast paced. [P1, Male, 30, League of Legends]*

> *I'm primarily a text communicator. It really hinders your ability to have more lengthy conversations with people. [P5, Male, 23, Overwatch]*

Players also note that when text chat is used, it is primarily task-oriented or used to express frustration.

> *So if someone talks through text, they're going to say it once in a while and say, "Hey maybe let's try this other thing". They're going to talk maybe five times throughout the whole match. If they're flaming then they'll talk a lot. [P12, Male, 18, Overwatch]*

Voice communication also better supports evaluations of social-emotional factors because the medium is rich with social cues like intonation and emotion [184]. In games where voice communication is the norm, intention for repeated play is more likely to be influenced by evaluations of both task- and social-emotional factors. As illustrated by P14:

> *It's a lot easier to connect with somebody who's voice you are hearing. In text chat, you can still get sort of a sense, and I have added some people who only would talk in text chat because they just didn't have a mic but again, that was partially because I thought they were good and the stuff they said in chat wasn't useless. [P14, Female, 24, Overwatch]*

> *As non-romantic as possible, it [voice chat] has a level of intimacy to it that text chat just doesn't. [P11, Male, 21, League of Legends]*

However, players note that voice communication is not always used even when it is provided. A possible reason is that the game provides other in-game communication tools that supplement the role of voice communication. Take for example the FPS game, *Apex Legends* [185], which has a robust ping and communication wheel system.

In this game, the in-game communication mechanics are sufficient for team communication (see Figure 10).

Figure 10 Apex Legends ping and communication wheel.

The ping and communication wheel system in Apex Legends is highly precise and specific which enables coordination without verbal communication. Source: LevelSkip [186].

As a result, voice communication is not frequently used despite its availability. In this instance, players' intention for repeated play is less likely to be influenced by evaluations on social-emotional factors. As illustrated by P7 who compared the experience of *Apex Legends* [185] with *Overwatch* [182]:

> *I find that a lot of times [in Apex Legends], using voice chat isn't necessary because of the communication menu they've set up in the game. I feel there's not a lot of communication in that game. When friendships are made it's probably because they play well together. I've been playing Apex Legends for a while and I haven't made any friendships through it... There's very little communication outside of the in-game mechanics. [P7, Male, 25, Apex Legends].*

Similarly, in the game *Dota 2* [170], using voice communication is not the norm, except to express frustration. Instead, text chat and pings are often used to coordinate actions and communicate with teammates.

> *In the game of Dota there is voice chat in the game, so you press a button and talk to your teammates [but] people don't use voice chat that much. People ping on the map and send text chats. Sometimes people send voice chat but normally that's when people are getting angry [P4, Male, 26, Dota 2].*

Thus, the presence of an in-game voice communication channel does not necessarily mean that players will use it. Evaluations on social-emotional factors are more likely to occur when strangers *actually* use voice communication.

3.5 Discussion

In this study, we investigated the factors that influenced players' intention for repeated play as a method of identifying proxy indicators of cohesion. This study was situated within the context of ad hoc teams in competitive team-based games. The findings from this study indicated that players intention for repeated play is influenced by unexpected bonds with strangers, evaluations on multiple task-related and social-emotional factors, and the communication medium. This occurs spontaneously as players do not typically enter the match with the intention or expectation of befriending strangers, supporting previous work [166].

Generally, strangers who signal a willingness to engage in teamwork are evaluated positively and seem to stand out. Players attribute this to the fact they do not necessarily expect teamwork to occur in an ad hoc team of strangers despite playing a team-based game. Strangers are also evaluated positively if they share a sense of humour, general interests, and values with the player. When strangers are positively evaluated on these factors, players are more likely to send them a friend request. The extent that players can evaluate strangers on these social-emotional factors, however, depends on the extent that strangers use voice communication. The availability of voice communication tools depends on the game.

3.5.1 Perceptions of cohesion can form quickly

These findings have several implications. While there is still contention on the time required for cohesion to emerge (i.e., Chiocchio and Essiembre [26] argued four weeks of interaction, Treadwell et al. [130] observed increased cohesion over a one-week period, Grossman et al. [39] found significant correlations between cohesion and performance in ad hoc teams), the fact that players send a friend request after a short first encounter suggests that cohesion may emerge even in such short-lived (i.e. ~30 minutes) situations. However, it is possible that the type of cohesion that emerges in such a short period is the 'swift' version. 'Swift' versions of emergent states are perceptions of assumed emergent states based on expectations 'imported' from other contexts. These perceptions are fragile and susceptible to early feedback but enable a team to work together assuming the presence of certain emergent sates [187], [188].

For example, 'swift trust' is a well-documented swift emergent state that is especially prominent in temporary virtual teams [187], [188]. In temporary teams who have to perform immediately, members *assume* trustworthiness and behave in a trusting manner until given reasons to behave otherwise. The empirical support for swift trust has led researchers to speculate about other swift emergent states [189]. Since 'swift trust' is usually observed in temporary teams, it is therefore plausible that cohesion observed in digital games STATs might be the 'swift' version. A longitudinal investigation of cohesion over time is required to validate this proposition.

Some evidence can be drawn from findings by Tyack et al. [166] who found that sending a friend request to a stranger after the first encounter is not uncommon. In their survey of 760 players from the MOBA genre, 82% of the sample stated that they had added a stranger to their friend list. However, 53% of them had added a stranger with whom they never played again. Participants of the present study also reported instances where they added strangers but eventually stopped playing with them or never played with them after the first encounter. Taken together, these findings seem to support the notion that early perceptions of cohesion may be malleable or weak [30], [74]. Further investigation is required to determine whether perceptions of cohesion formed during this short initial encounter is qualitatively different to

cohesion perceptions formed at a later period. Nonetheless, these findings suggest that perceptions of cohesion can emerge in such brief moments of interaction – competitive team play seems to provide sufficient information, events, and experiences to influence the emergence and development of cohesion in ad hoc teams.

3.5.2 Factors map onto task and social dimensions of cohesion

A second implication is that the task- and social-emotional factors identified in this study seem to map onto the task and social dimensions of cohesion. Task cohesion refers to the shared sense of commitment and unity toward achieving the team task or goals that drive the attraction or bond within the team [13]. Being communicative and responsive, providing encouragement and positive sentiment in the face of adversity, and giving and responding positively to constructive feedback contributes to task cohesion. When strangers engage in these teamwork behaviours, defined as "members' interdependent acts that convert inputs to outcomes through cognitive, verbal, and behavioural activities directed toward organising taskwork to achieve collective goals" [56], it signals that they are committed and unified in achieving the team's goals. A team composed of individuals who are likely to value, be committed to, and prioritise the team task is likely to become cohesive [13], [190]. Hence, perception of task cohesion likely increases when strangers engage in teamwork, which in turn positively influences intention for repeated play.

These findings are supported by previous research on players from *League of Legends* [68]. Freeman and Wohn [164] found that collaborative knowledge sharing (similar to the factor of constructively giving and receiving feedback) contributes to the development of social relationships between players. Similarly, Kou and Gui [64] found that factors such as keeping a positive attitude and maintaining a positive atmosphere contribute to effective team functioning in ad hoc teams. Together, these findings suggest that teamwork processes not only contribute to the performance of a team, but also to the emergence of affective states such as cohesion. This is in line with the overall theory of team functioning by Marks et al. [56] and corroborated by

LePine et al.'s [81] meta-analysis showing a strong positive correlation between teamwork processes (i.e., transition processes, action processes, and interpersonal processes) and cohesion.

Social cohesion, on the other hand, refers to the attraction within the group because of positive relationships with other members of the group [13]. It reflects shared bonding and liking among team members. When a stranger exhibits social-emotional characteristics similar to the player, such as having a shared sense of humour, general interest, and values, it contributes to social cohesion by increasing interpersonal attraction. Previous research shows that people like, and are attracted to similar others especially in the early stages of a team [159], [160], [190], [191]. For example, Launay and Dunbar [192] investigated whether people more positively evaluated strangers who shared more traits with them. They found that the likeability rating of a stranger linearly increased with the number of shared traits. In a similar vein, Freeman and Wohn [164] investigated how amateur and professional League of Legends players selected future teammates. Their findings showed that in addition to being skilled and willing to communicate, having a positive attitude and compatible personality are part of the selection criteria. Combined with the findings from the present study, it suggests that social cohesion in newly formed teams is driven by shared and compatible non-game characteristics such as interests, personality, and attitudes.

3.5.3 Factors manifest through communication

The findings from this investigation suggest that (1) cohesion can emerge in *ad hoc* teams (possibly as a 'swift' version) and (2) cohesion arises through factors that contribute to effective teamwork (i.e., task-related factors) and pleasant social dynamics within the team (i.e., social-related factors). This begs the question of how these cohesion-building behaviours can be cultivated. With the exception of the skill and competence factor, a key observation from this study is that task- and social-emotional factors are expressed through communication In digital game teams, communication may play a more pivotal role in influencing player's perceptions of each other, and consequently perceptions of cohesion. This contrasts with non-digital

game teams where team members have access to other types of influencing information such as title, age, gender, and nationality. For non-digital game teams, these overt surface-level variables are thought to dominate team member's perceptions of each other during early team interaction [190]. It would be interesting to explore the extent that non-digital game teams rely on communication to express these factors.

The task-related factors of being communicative and responsive, providing encouraging and positive communication in the face of adversity, and responding positively to and providing constructive feedback are expressed and manifest through communication rather than in-game behaviours like movement. Similarly, the social-related factors of expressing humour, sharing general interest, and sharing values can only be uncovered through communication. This is unsurprising, given that research on fast-paced ad hoc teams shows that communication serves multiple instrumental and social functions [108]. Similarly, Eklund and Johansson divided the interactions in temporary digital game teams into instrumental and social categories [193]. It should be noted that due to the frantic rhythm of the game, ad hoc teams in competitive team-based games, primarily communicate through non-verbal in-game communication tools such as pings and targeted messages (i.e., 'on my way') [181], [194]. Pings allow players to quickly broadcast changes in the environment while targeted messages enable limited coordination. However, if teams want to coordinate elaborate strategies or provide feedback on a game event, they need to use the voice or text options. This suggests that a direct investigation of communication behaviours exhibited by the team will allow us to (1) corroborate the findings from this investigation and (2) identify specific communication content and patterns that might contribute to the development of team cohesion.

Research in the sports literature alludes to the role of communication on cohesion. Studies on athletes of various sports show that constructive communication forms and the extent that team members exchange task-related information is positively correlated with task cohesion [19], [103], [195], [196]. Moreover, a meta-analysis of team communication showed that communication frequency and cohesion are

positively linked (ρ = .31, k = 5) [69]. Therefore, it is plausible that a direct investigation of communication behaviours will provide greater insight into how cohesion develops in fast-paced ad hoc digital game teams.

3.6 Limitations and Future Work

This study has limitations, one of which is the use of a single coder. Since the data were primarily analysed through my lived experience as a player, the analysis was limited to a single perspective. This may have introduced biases in how the data were interpreted, limited the range of concepts that were developed, and subsequently affected how the data were coded. In future, at least two coders should be involved in the qualitative analyses to overcome these limitations. Additionally, inherent to any deep qualitative approach, the findings lack generalisability despite providing useful insights. However, it is a useful first step to identifying proxy indicators of cohesion in ad hoc teams.

Another limitation of conducting interviews is that it relies on a retrospective account of events. For this study, it requires the participant to be aware of the influence of strangers' actions on their own actions. Therefore, while players may *report* adding strangers to their friend list due to the aforementioned factors, behavioural data is required to corroborate these reports. Future work should follow the lead of Spink et al. [1], [140] who, in separate studies, investigated factors that led to the *intention* to return to a team and further validated those findings by showing that those factors do in fact lead to *actual* return to a team. For instance, one could conduct a mixed-methods study where a player is observed throughout the match in an ad hoc team. If the player adds a stranger to their friend list, the researcher can analyse the game data and interview the player for their reasons. Using a combination of qualitative and quantitative data will allow a more comprehensive understanding of factors that give rise to repeated play.

The findings from this study could also be strengthened by including the influence of skill tier (e.g., rank). Future investigations could focus on how skill tier may moderate the relationship between task-related factors and intention for repeated

play. At higher tiers, players are generally more skilled. As such, they are likely to know how to play effectively with their teammates. For instance, previous research has found differences in the movement of teams between novice and expert players in *Dota 2* [197]. This would imply that players at the higher tiers do not stand out as strongly as those in the lower tiers when they exhibit teamwork behaviours. Task-related factors may not be as foundational to intention for repeated play. Thus, it is possible that the extent that task-related and social-emotional factors influence intention for repeated play is moderated by skill tier. These limitations require further exploration.

3.7 Conclusion

In summary, this study identified four task-related factors and three social-emotional factors that players either consciously or unconsciously evaluate strangers on. A positive evaluation on these factors gives rise to intention for repeated play (which manifests as sending a 'friend request' to the stranger or inviting them back for a subsequent match), a proxy indicator of cohesion. Additionally, the extent that players can evaluate strangers on social-emotional factors depends on the extent that voice communication is used by the player. Importantly, the findings indicate that both task- and social-emotional factors manifest through communication. Thus, future work could investigate team communication behaviours to further corroborate these findings.

Chapter 4: Analysing team communication data: a pilot study

In this study I piloted a method for analysing team communication textual data. Since team research is extremely time and resource intensive, I chose to use a simpler, team-based game to test initial hypotheses, data collection, and data analysis methods. The cooperative puzzle-solving game, *Portal 2*, a two-player person-versus-environment game, was appropriate for the pilot study because it was a simple and straightforward team environment with few additional factors to control. The findings from this investigation suggests that communication volume and performance is negatively linked but communication volume may be positively linked to the development of social bonds between strangers. The findings imply that communication frequency may be used as an indicator cohesion. This was investigated in the Chapter 5.

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I was first author on this paper. I designed the research study and performed all the data collection, data cleaning, and analysis. I led the writing of the paper with my co-authors.

4.1 Abstract

Teamwork is challenging in cooperative digital games, especially between strangers. In many online cooperative games, teams have a short-lived existence and ever-changing membership. Our study explores how short-lived, ad hoc teams of strangers communicate and investigate its effect on team performance. We use the commercial cooperative digital game, *Portal 2* and analyse 2256 text message instances produced by 33 teams during a 45-minute interaction. Our findings suggest that team communication is negatively related to performance and affects performance over and beyond prior experience. A content analysis shows that teams generally have higher task-related communication than socio-emotional communication. This pattern is consistent throughout the duration of the interaction period. The results are discussed in the context of previous research on team communication and performance, and we draw parallels with communication patterns in real-world groups such as aviation crews.

4.2 Introduction

Digital games have become an avenue for people to develop social connections and make new ones [153], [198], [199]. For example, after lockdown measures were introduced globally during the start of the 2020 coronavirus pandemic, Microsoft reported a 130% increase in multiplayer gaming and 23 million new friendship connections made over their Xbox Live service from March to April 2020 [200]. Additionally, a recent report shows that multiplayer titles, especially those with cooperative elements, are well-represented in the 20 most popular PC games [62]. This shows how important the social aspects of digital games, e.g., interacting with others in some way, are to game success.

Our study focuses on cooperative games. Cooperative games range from simple two-player, fully cooperative environments like *Portal 2* [201] and *Ibb & Obb*

[202], to more complex games with teams of five or six players in mixed cooperative-competitive environments like *League of Legends* [68] and *Counter-Strike* [132]. Regardless of the complexity, or presence of competitive elements, one of the core challenges presented by cooperative games is to effectively work together.

Within cooperative games, our study specifically investigates online teams of strangers. With over 2.5 billion players worldwide [203], playing with strangers is common in online multiplayer games. In cooperative games, working effectively as a team of strangers is challenging. The familiarity that comes with pre-existing relationships makes it easier to predict the actions, behaviours and mental models that a teammate might have. However, when there is no familiarity, teams of strangers can easily run into problems of coordination and communication [204], [205]. Due to the large player base, many online cooperative games employ some form of automatic matchmaking to help players find teams and join games quickly [206]. As a result, a team's existence is usually constrained by the duration of the game. This short-lived existence (e.g., 30-45 minutes) further challenges teams' ability to develop processes that facilitate effective teamwork. This unique context invites questions about the underlying mechanisms supporting effective teamwork in ad hoc teams of strangers in digital games.

To this end, we investigate *team communication* between strangers, specifically text chat, using the commercial puzzle-solving game *Portal 2* [201]. We focus on team communication because it is necessary for teamwork -- it is the means by which team members combine their knowledge, coordinate actions, and develop affective relations [85]. As such, it provides an index of the emerging dynamics in the team and its subsequent impact on performance and personal relations. We chose to focus on text rather than voice communication as we wanted to replicate the anonymous environment that players often experience when playing in ad hoc teams. Additionally, given the overarching goals of this thesis chapter, text chat had the clearest and simplest method of extraction compared to voice or pings.

We selected *Portal 2* ([201]; description in Section 4.4.2) because it allows us to focus on the communication between two strangers in a controlled manner. Since *Portal 2* [201] focuses solely on going from point A to point B without distractions, any observed communication effects can be more clearly attributed to player behaviour. By investigating team communication in this context, we hope to advance our understanding of what makes effective ad hoc teams of strangers.

4.3 Related Work

4.3.1 Communication and Performance

Team communication as a predictor of performance has been studied widely outside of digital games. Theoretically, communication enables team members to send and receive information regarding the environment, to formulate strategies, make decisions and coordinate actions [56, p. 2]. Its role in enabling team processes makes team communication a key determinant of performance. This has been confirmed in a meta-analysis on 150 studies containing over 9000 teams, showing that communication is significantly and positively (ρ = 0.31, 95% CI [0.23, 0.30]) related to team performance [107]. Although the meta-analysis did not include teams in digital games, we expect to find a similar relationship since a variety of team types were included in the analysis.

H1: Team communication will be positively related to performance

4.3.2 Communication Content

The relationship between communication and performance might be moderated by the communication content. While there are nuances, communication in groups can generally be categorised as task-oriented or socio-emotional (or relational) [114]. Socio-emotional content develops the climate or atmosphere within a team, which can have an influence on teams' progress on a task, but task-oriented content is likely to have a direct link as it pertains to ‘getting the job done' [56]. Thus, we hypothesise:

H2: Task-oriented communication will be more strongly related to performance compared to socio-emotional communication.

In teams of strangers with short-lived interactions, we also expect communication to be mostly task-oriented. Previous research investigating the communication content in digital game teams has found higher socio-emotional compared to task-oriented communication [115], [207], [208], owing to the recreational nature of games. Socio-emotional content made up 50% of communication in a study of *Counter-Strike* [132] teams, with 25% of content relating to game strategy [207]. Similar findings were observed in a study of *Jedi Knight II* players [115], [209]. However, we expect the opposite pattern because our study focuses on teams of strangers, whereas these studies have investigated long-term groups and teams. When future interaction is expected, individuals tend to engage in more positive, and relational forms of communication [210]. In swift starting teams, communication tends to be more task-oriented [52].

Although digital games are inherently recreational and playful environments, the formation and life span of the team will influence social interactions. Research on zero-history computer-mediated work groups have generally observed higher task-oriented communication if the team has been formed for a short-term, time-sensitive purpose [210]. Parallels can also be drawn with real-world teams with similar structure (i.e., zero-history, short-lived, time sensitive), such as crisis teams and airline crews.

The higher levels of task-oriented communication observed in these swift starting action teams is attributed to the task- and performance-driven environment that the teams operate in [52], [129]. These teams work under evident time pressure and must perform almost immediately upon formation. While the playful nature of games suggests that higher levels of socio-emotional content would be observed in teams of strangers in digital games, we expect that the short-lived nature of the team functioning in a problem-solving environment (*Portal 2)* will engender higher task-oriented communication.

H3: Team communication will be more task-oriented than socio-emotional

4.4 Method

4.4.1 Participants

66 participants, comprising university students and staff members, were recruited via advertisements and word of mouth. The call-for-participants advertisement noted that the study was open to people with any experience level of digital games and was not exclusively focused on gamers.

23 participants identified as female, 1 identified as non-binary, and 42 identified as male (M = 21.9 years old, *SD* = 6.51, range = 18-64 years old). Participants were placed in 33 two-person teams, where they were matched based on availability, and where possible, their level of experience with the game.

Since *Portal* is a popular franchise, it is possible that participants had previous experience with the game and would know the solution to the levels. Level of experience can be considered a confounding variable to the communication-performance relationship. Level of experience was operationalised as the number of hours participants reported previously having played either *Portal 1* or *Portal 2* [201]. In 42% of the sample, the more experienced participant in the team had spent at least 50% more time on the game than the less experienced participant. To the best of our ability, we tried our best to match participants based on overall level of experience.

4.4.2 Materials and Measures

Portal 2 Cooperative Mode

Portal 2 [201] is a three-dimensional, ‘first person perspective' puzzle-solving digital game. It has a single player mode and a two-player, cooperative mode. This study refers to the cooperative mode when using the term *Portal 2*.

Portal 2 [201] *i*s easy to learn. As such, it is suitable for people with varying levels of experience with digital games. In *Portal 2* [201], each level is a puzzle. Successfully solving each puzzle means that the team is able to get from the start to the end of the level. Throughout the levels, players need to move items to specific positions, time their actions and move in turns. Players use 'portals' to carry out these actions (Figure 11). Hence, advancing through the levels requires cooperation, communication and coordination. This allows us to investigate dyadic social interactions in a relatively naturalistic manner.

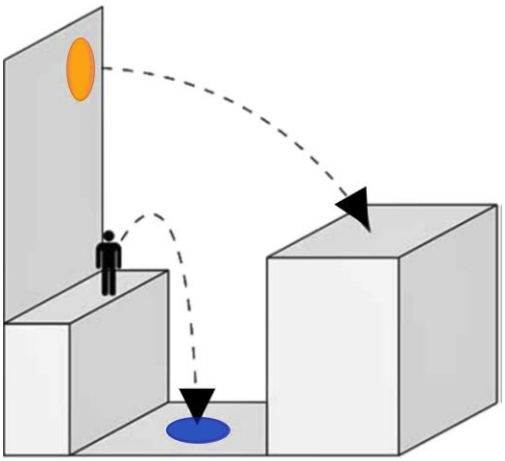

Figure 11 Portal 2 core mechanics.

Adapted from Shute, Ventura and Ke [211]. Illustration of the core mechanic in Portal 2 – creating portals. Players create two separate portals that allow them to move between surfaces: a blue portal to enter and a yellow portal to exit.

There are three ways to communicate in *Portal 2* -- using text chat, voice chat and in-game communication mechanics like 'pings', and 'gestures'. 'Pings' are semantically imbued, task-oriented, attention-focusing tools while 'gestures' are socio-emotional animations [180]. For this study, participants were only allowed to communicate using text chat and in-game communication mechanics. This was to ensure full anonymity between participants. This study focuses on text chat analysis.

Bales' Interaction Process Analysis (IPA)

Text chat instances were coded using Bales IPA [114]. An 'instance' represents separate lines of text chat sent by a player (see Table 3).

Table 3 Sample of coded text chat instances.

player	Sentence	Code
1	go ahead	4
2	k	3
1	woo teamwork	1
2	what are we doing?	9
1	it only opens briefly	6

Each row is an instance and each instance is assigned a code that corresponds to the coding scheme.

Bales IPA was developed to understand the underlying processes that drive group interaction [114]. It consists of 12 categories that make up 4 higher-order categories: (1) *Socio-emotional: Positive Reactions*, (2) *Task area: Attempted Answers*, (3) *Task area: Attempted Questions*, (4) *Socio-emotional: Negative Reactions*. During the years, Bales IPA has faced some criticism for not accounting for communication content that contains multiple processes [212]. We acknowledge this criticism; we selected it because its higher-order categories provide a succinct summary of the verbal communication processes observed during the interaction between strangers in a cooperative task. This enables us to understand how communication processes might affect team performance and the overall dynamics in the team. To mitigate the limitations of Bales IPA, communication instances were coded based on their *primary* purpose.

Bales IPA has also been found to be suitable for the digital game context, although it is missing some categories that are typically observed in computer-mediated interactions. For example, communication content that is intended to correct for message errors (e.g., typos) and communication content that is not immediately related to the task. Nonetheless, it has been successfully used to investigate the presence of socio-emotional and task-oriented communication produced by players in a multiplayer game [213]. 14 categories in total were used to code the text communication between strangers in *Portal 2* ([201]; Table 4).

Table 4 Bales' IPA Functional Codes (1-12) with Two Additional Codes (13 & 14).

Higher Order Category	**(Code) Category Description**
Socio-emotional: Positive Reactions	*(1) Shows solidarity/seems friendly: Any act that shows positive feelings towards another person* *(2) Shows tension release: Any act that reduces the anxiety that a person or group may be experiencing* *(3) Agrees: Any act that shows acceptance of what another person has said*
Task-area: Attempted Answers	*(4) Gives suggestions: Any act that offers direction/action for how to engage the task* *(5) Gives opinions: Any act that advances a belief or value that is relevant to the task* *(6) Gives orientation/information: Any act that reports factual observations or experiences*
Task area: Questions	*(7) Asks for orientation/information: Any act that requests factual observations or experiences* *(8) Asks for opinions: Any act that requires a belief or value that is relevant to the task* *(9) Asks for suggestions: Any act that requests direction/action for how to engage the task*
Socio-emotional: Negative Reactions	*(10) Disagrees: Any act that shows rejection of what another person said* *(11) Shows tension: Any act that indicates that a person is experiencing anxiety* *(12) Shows antagonism/seems unfriendly: Any act that shows negative feelings toward another person*
Non-task Related Information and Questions *Correction*	*(13) Any content that does not immediately apply to the task* *(14) An instance that is meant to correct a typo or grammatical error*

4.4.3 Procedure

This study was approved by the Ethics Committee of the Department of Psychology. The goal of the experimental setup was to maintain full anonymity between players, similar to the situation in online digital games. To achieve this, team members were emailed separately and were told different arrival times. This was to minimise the chance of players encountering each other in-person. Upon arrival, participants were seated in separate rooms with all windows covered.

Participants were given an information sheet detailing the aims of the study and provided informed consent. Participants were told that voice communication was disabled but that they could communicate with their teammate via text chat. Sticky notes containing information about controls such as moving, jumping, chatting and interacting with items in the game were stuck around the computer. This was to aid inexperienced participants.

All teams started from the *Portal 2* [201] tutorial level and were given 45 minutes to play through the game. Upon completion, participants were thanked and were shown out of the lab separately.

4.5 Results

4.5.2 Communication and Performance

We first analysed the relationship between team communication and performance. Team communication was operationalised as communication frequency. Performance was operationalised as the number of levels completed by the team. The tutorial level was not included in this analysis because the level was meant to teach participants how to interact with the game environment. Levels that were partially completed were also not included. The mean levels completed was M=6.15, SD=4.26.

A *negative* correlation between communication frequency and performance was observed, $\rho = -0.36$, $p < .038$ (Figure 4). While our findings provide support for the

link between team communication and performance, the observed negative effect is opposite to the effect found in Marlow and colleagues' [15] meta-analysis. Hypothesis 1 (*Team communication will be positively related to performance*) is not supported. Note that a non-parametric correlation was used due to the differential distance between game levels in terms of difficulty (e.g., getting from level 10 to 11 is not the same as getting from level 1 to level 2).

4.5.3 Communication Content

To analyse the communication content, three coders independently coded all the data. After the first coding round, the coders came together to resolve disagreements and clarify code descriptions. The coders then had the opportunity to recode the dataset. In the second coding round, when there were disagreements in the code, the code defaulted to the lead researcher. One team was removed from the analysis because they did not produce any textual communication *n = 32*. Fleiss' kappa showed that there was good agreement between the raters, κ = 0.69 (95% CI, 0.68 to 0.70), *p* <.005.

We ran a correlation to test Hypothesis 2 (*Task-oriented communication will be more strongly related to performance compared to socio-emotional communication*). Task-oriented communication, ρ = -0.54, *p* <.001 had a stronger correlation with performance than socio-emotional communication, ρ = -0.14, *p* <.446, although the relationship between socio-emotional communication and performance was not significant. Hence, Hypothesis 2 was partially supported.

We then analysed the differences in communication content frequencies. Of the 2256 communication instances, the most frequent categories were giving suggestions/directions (25%, code 4), showing friendliness (16%, code 1), sharing observations and experiences (12%, code 6), and giving opinions (11%, code 5). There was no negative, unfriendly or hostile communication (code 12) (see Figure 12).

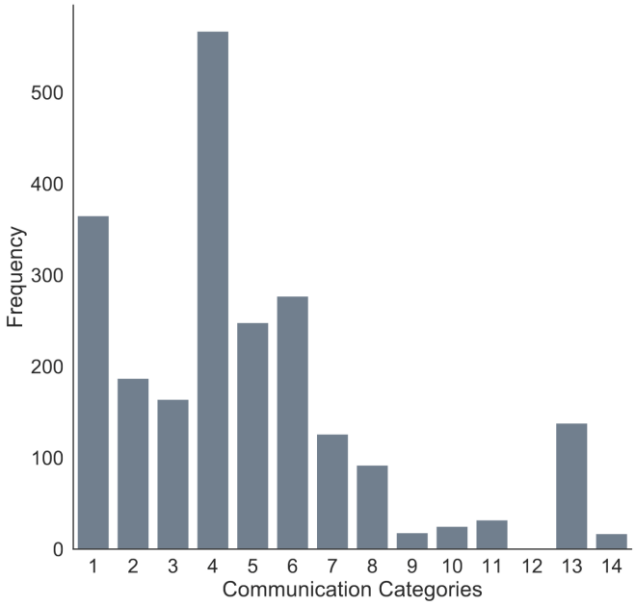

Figure 12 Frequency of communication categories.

Refer to Table 4 for category codes and corresponding descriptions. The Y axis represents the number of instances a category occurred.

When grouped into their respective higher-order categories, the findings indicate that communication was most frequently used for task-related purposes (see 'Higher Order Category' column in Table 5). The frequency of task-related communication (asking questions and giving answers) was almost double of socio-emotional communication (59% vs 34%), supporting Hypothesis 3 (*Team communication will be more task-oriented than socio-emotional*).

Table 5 Distribution of Higher-Order Categories in Team Communication.

Category	**% total comms.**
Socio-emotional: Positive	31%
Task: Answers	48%
Task: Questions	11%
Socio-emotional: Negative	3%
Additional	7%

4.5.4 Additional Analyses

Level of experience, performance, and communication

In addition to the hypothesis testing above, we explored the effect of experience on team performance. All 33 teams were included in this part of the analysis. Since we did not create novel [201] chambers, participants with previous experience with the game will not only be more familiar with the mechanic but will likely remember the solutions to the puzzles. This may influence team performance, communication and the relationship between communication and performance.

The level of experience in a team was operationalised as the sum of the number of hours that each participant had previously spent on *Portal (1 or 2)*. The mean level of experience (hours) in a team was M = 13.97, SD = 15.38. A strong and significant relationship between the level of experience in a team and performance was found $\rho = 0.76$, $p < .001$ (Figure 13 (right)). The strong correlation suggests that the level of experience within a team and performance are linked. However, no significant correlation between the level of experience within a team and volume of team communication was found (Figure 13 (left)).

Given the strong correlation between experience and performance, we investigated the effect of communication, controlling for level of experience. Since task-oriented communication had a stronger correlation to performance than total communication, we used only task-oriented communication for this analysis. Before running the analysis, the independent variables were examined for collinearity. Results of the variance inflation factor (all less than 2.0), and collinearity tolerance (all above 0.8) suggest that multicollinearity was not a concern. An inspection of the P-P plot and the scatter plot of residuals indicate that the data also met the assumptions of normality and homoscedasticity. A hierarchical linear regression was run.

In the first step of the regression, only level of experience within a team was included as a predictor of performance. This model was statistically significant, $F(1, 31) = 28.30$, $p < .001$, and explained 48% of the variance in performance. In the second

step of the regression, level of experience within a team and task-oriented communication were included as predictors of performance. The second model was also statistically significant, F(2, 30) = 22.85, *p* <.001, and explained 60% of variance in performance. Task-oriented communication explained an additional 13% of variance in performance, after controlling for experience (R2 Change = 0.126, F(1,30) = 9.57, *p* <.005). These findings indicate that communication contributes to team performance, over and above prior experience.

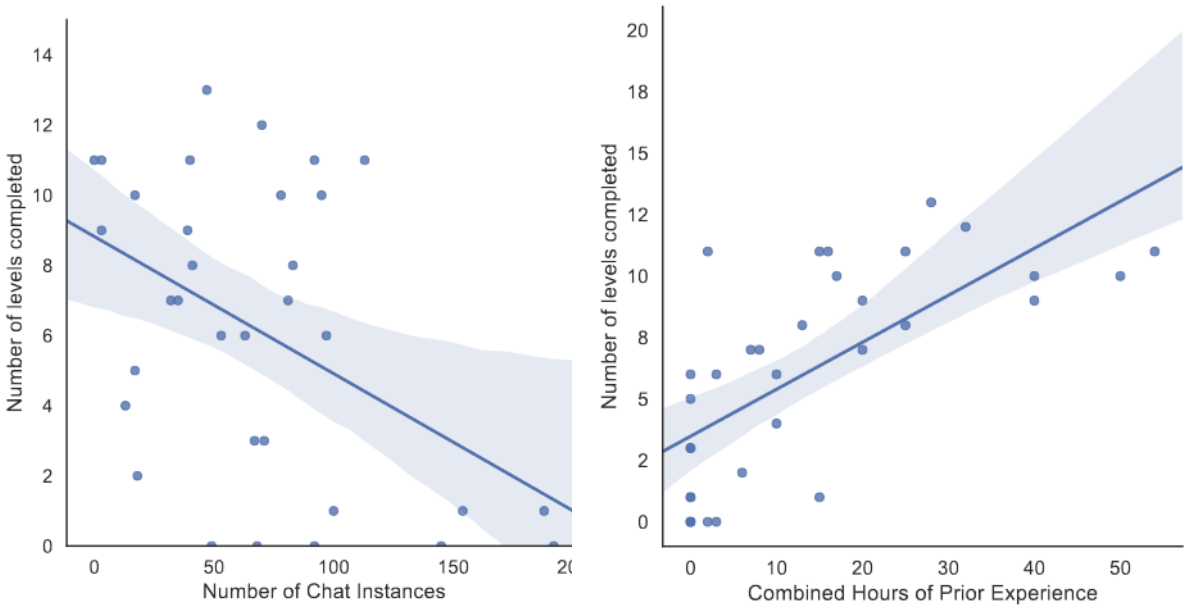

Figure 13 Communication-performance and experience-performance correlations.

Left: *A significant negative correlation between team communication and performance, ρ = -0.36, p <.038.* ***Right:*** *A significant positive correlation between level of experience and performance, ρ = 0.76, p <.001. 95% confidence interval is indicated by shading around the line.*

4.5.5 Communication Dynamics

We then explored the communication dynamics. Teams differed in their volume of communication and levels of communication dominance. 20 teams had above 60% communication dominance by the more talkative player (see Figure 14), suggesting

that, in general, one team member was producing more communicative instances than the other.

We also investigated whether the frequency of communication categories changed over time. One might expect task-oriented communication to decrease as teams become more familiar with the game mechanics. Similar to Section 4.5.3, only teams with text communication (n = 32) were used for this analysis. Figure 15 shows that the distribution of the frequency of categories remains relatively stable throughout the interaction. There is much more communication related to providing information compared to asking for information, and the valence of communication is highly positive. Together, these communication patterns indicate that team members are constantly giving unsolicited suggestions/information. The high level of friendliness and absence of negative communication indicates a positive and cooperative climate.

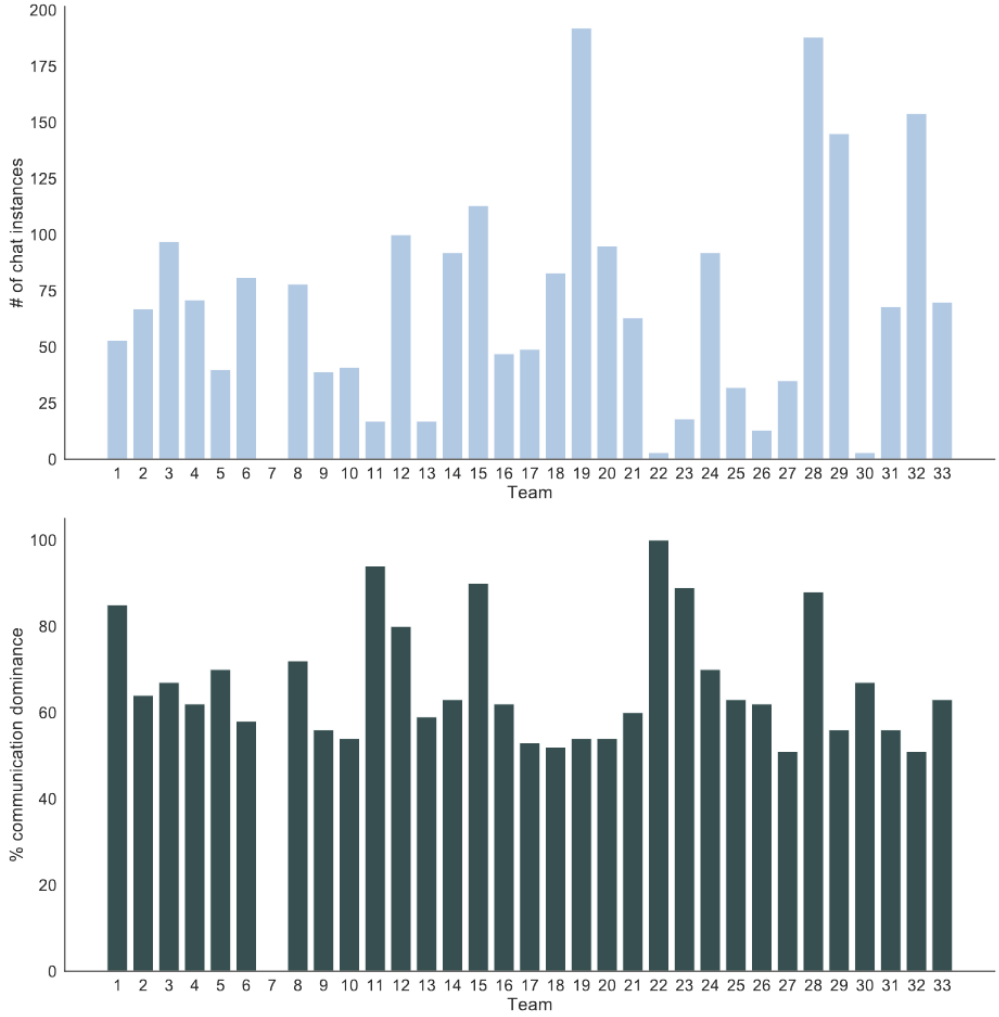

Figure 14 Communication distribution within a team.

Comparison of total team communication and the percentage of communication attributed to the more talkative team member. Team 7 did not produce text chat.

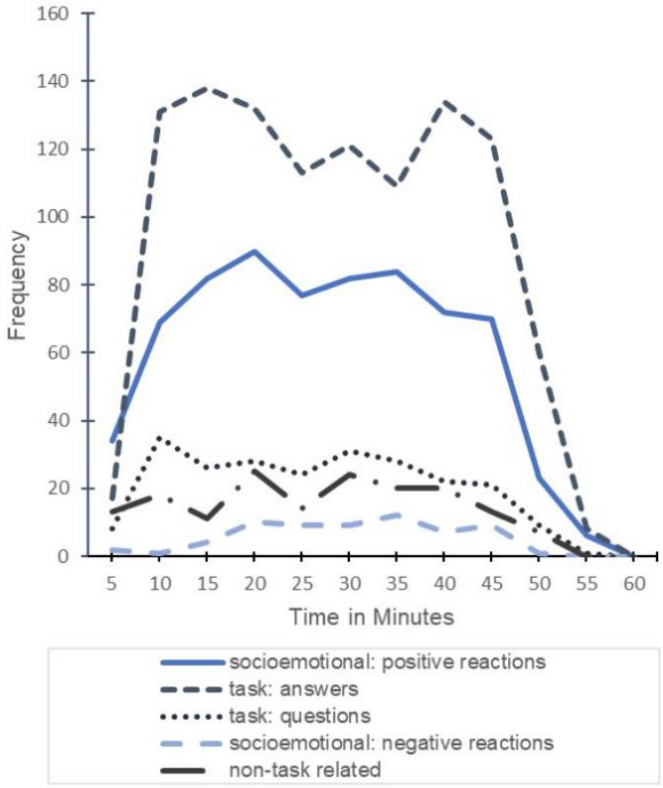

Figure 15 Communication category distribution over time.

Frequency of higher-order communication categories over time. Communication related to giving instruction was the most frequent throughout the interaction, but high levels of positive reactions indicate a positive, cooperative team climate.

4.5.6 Summary

In ad hoc teams of strangers, (text) communication and performance seem to be negatively linked, i.e., teams that communicate less perform better. Although the direction of effect is opposite to previous research [107], it supports the communication-performance relationship. Additional analysis showed that communication explains 13% of variance in performance in teams of strangers, above and beyond prior experience. In line with observations of communication in real-world ad hoc teams, and zero-history computer-mediated work groups, we found higher levels of task-oriented communication compared to social communication. This is in contrast to previous research indicating that higher socio-emotional communication is expected due to the recreational, playful nature of digital games [208], [213].

Our exploratory analysis of communication dynamics indicated that team communication was dominated by one team member. Nonetheless, the high level of positive socio-emotional communication suggests that the climate in teams was generally positive and cooperative.

4.6 Discussion

By looking at team communication, our study takes a small step towards understanding the underlying mechanisms supporting effective teamwork in ad hoc teams of strangers in digital games. It also highlights the unique context of digital games – which has both recreational and performance-driven purposes – and whether theories of team effectiveness, which is largely based on work teams, applies.

Beyond digital games, our study highlights the value of off-the-shelf games as research tools for studying team dynamics. We show that by analysing communication, even during a short 45-minute interaction, rich and complex social interactions can be observed. These observations serve as objective indicators of the emerging dynamics in a team, and how it relates to various outcomes like performance. Using off-the-shelf games and conducting communication analysis are some of the recommendations that have been made to advance research on team process dynamics [57]. We discuss our findings in the next sections.

4.6.1 Team Performance

The strongest predictor of performance, accounting for 48% of variance, was the level of experience participants had with *Portal 2* [201]. This is expected since we used default rather than custom levels. Participants with previous experience are familiar with the mechanics and may already know the solutions. This gives teams with more experienced players the upper hand. However, team (task) communication explained an additional 13% of the variance. If this relationship is causal, it implies that improving task communication efficiency can positively impact performance. Indeed, this is the case for aviation crews where training resources have primarily been directed to improving team communication processes rather than improving

individual expertise [129], [214]. This suggests that designing systems that help players communicate more efficiently may help players who are strangers work better together.

The negative correlation between communication and performance was surprising. The nature of the study limits our ability to identify causality or direction of effect. On one hand, it suggests that poor communication is detrimental to performance. Since teams were given a time limit, the negative relationship between communication and performance may reflect time spent deliberating on actions (via text chat). This in turn reduced available time for executing actions, which led to the observed relationship. On the other hand, the negative correlation could also indicate the team's inability to perform. This may be driven by the imbalance in level of experience in the team, where the less experienced player is forced to ask more questions and the more experienced player is forced to give elaborate responses in order for the team to progress. Both explanations are possible but unfortunately could not be teased apart further.

Digital games also provide quick feedback loops on actions. If it is indeed communication driving performance, we speculate that teams with less communication might have higher performance because they spend more time trying possible solutions rather than discussing. Discussion may only be required when teams encounter difficulty and difficult levels impair performance. Toups and colleagues [59] made a similar observation in communication improvements of firefighting teams. An improvement in team coordination and performance was related to a reduction in verbal communication. Since the combined level of experience is strongly correlated with performance, it would also suggest that in more experienced teams, players tend to type less and act more.

Another possible explanation for the negative relationship is that our analysis did not include in-game communication mechanics. Digital games have various in-game communication mechanics that allow players to communicate information by directly using the game system [180]. In-game communication mechanics allow

players to communicate more efficiently [180]. For example, non-linguistic ‘pings’ are used to direct attention to a certain location in the environment and may convey meaning and intention.

In a study comparing the effect of different communication mediums on performance in *Portal 2* [201], participants reported how in-game communication mechanics helped them elaborate information quickly [215]. On the contrary, explicit communication like text chat has high *communication overhead* – ‘the cost in terms of time, cognitive bandwidth, and technological bandwidth of sharing information with other team members.’ [180]. Although useful for explanations, conveying information via text chat takes longer than using in-game communication mechanics like ‘pings’, where information can be communicated using a single mouse click. This suggests that the relationship between communication and performance may be positive if in-game communication mechanics were included in the analysis. However, assuming communication influences performance, it might be that communication has a curvilinear relationship with performance such that communication is beneficial until teams know how to implicitly coordinate. Some evidence may be drawn from the team that was removed from the communication analysis. Despite having no text chat, the team completed 11 levels (the highest number of levels completed is 13).

4.6.2 Communication Content

In contrast to previous research on communication content during cooperative play [207], [208], [213], we found a higher volume of task-oriented communication compared to socio-emotional communication. It is possible that Pena and Hancock [213], who also used Bales IPA, observed the opposite trend (77% socio-emotional communication, 23% task communication) because their sample were members of the same ‘clan'. Clan members have ongoing relationships, which would manifest in the way they communicate with each other -- exhibiting greater positive communicative behaviour to maintain cohesion and satisfaction within the group [193]. Hence the difference between our findings may be attributed to the absence of prior relations and absence of anticipation of future relations. Similar patterns have

been observed in ‘pick-up groups' in *World of Warcraft* [193] and are alluded to in an interview study of interacting with strangers in *League of Legends* [64].

The communication patterns in our findings more closely reflect the dynamics in ‘swift starting action teams' such as airline crews [216] and military teams [125]. Communication tends to be highly task-oriented because these teams do not assume pre-existing socio-emotional ties [125], [129], [216]. However, we suspect that the communication dynamics would be different if teams of strangers were not in a time sensitive, performance-focused environment. Hence, it is possible that the interaction between team characteristics -- a team comprised of strangers, and task characteristics -- highly interdependent and requiring immediate action, may be driving the observed dynamics. Nonetheless, in digital games where ad hoc teams of strangers had to perform immediately, communication is likely to be predominantly task-oriented until the team disbands.

On a separate note, since digital games support the development of new social connections [200] and cooperation has been found to facilitate friendship development [217], this could mean that the degree to which strangers effectively collaborate might forge bonds that turn into friendship. Therefore, if we design systems that facilitate more effective collaboration between strangers, it could not only benefit performance but influence the development of social ties between players who are strangers.

4.6.3 Communication Dynamics

The high volume of communication related to giving information relative to communication related to asking for information throughout the interaction suggests that players may be giving unsolicited information. While this can be perceived and received negatively, the high level of positive socio-emotional communication throughout the game, indicates a positive team climate. This may be attributed to the environment – teams operated in a context with no competitive element, where cooperation was obviously the only route to success. Hence it is in the team’s interest

to foster a cooperative environment, which manifests as high levels of positive socio-emotional communication.

Another possibility is that early interactions had set the tone for subsequent interactions. When teams have no prior history, early interactions set the expectation for future behaviour [218]. These interactions tend to persist and have pronounced effects of subsequent communication [219], [220]. Jung and colleagues [220], for example, predicted team performance up to 6 months in advance using just 15 minutes of data on interaction dynamics from 30 teams. Given that digital games offer immediate feedback on actions, it is possible that the early positive and cooperative interactions have set the expectation for subsequent interactions.

4.7 Limitations and Future Work

By investigating communication dynamics, the work presented here extends previous research on the social interactions between strangers in team-based digital games but carries some limitations. Firstly, although our sample size is larger than some previous studies examining communication in *Portal 2* (e.g., n = 20; [215]), it is still relatively small. A power analysis using *G*Power* [221] shows that a sample of 33 two-person teams, and effect size of |0.36| for the correlation between communication and performance provides 0.57 power. Our findings should therefore be interpreted with caution and a larger sample size would improve statistical significance.

Our findings present only a partial picture of team communication dynamics since in-game communication mechanics were not incorporated into our analysis. By including the different modalities of communication, for example, voice chat and pings, a more comprehensive understanding of the relationship between communication and performance can be gained. For example, we hypothesise a positive relationship between ‘pings’ and team performance given that it reduces communication overhead [222], and allows information to be conveyed quicker than typing. Nonetheless, investigating text chat has provided some insight into the potential issues that inexperienced players face when using communication systems.

It also highlights the type of communication that players would find most useful when working with strangers.

Our study also had a wide range of expertise which was useful in that it provided a wide spread of performance. However, it may have swamped the potential effects of personality and individual differences in communication ability. Further studies may try to use players with a smaller range of expertise – perhaps only recruiting novices. Having similarly experienced team members would enable us to address questions on how the level of expertise in a team influences communication patterns, as there is some evidence that it does [59]. These limitations imply that our findings may only reflect situations where there is an obvious experience gap between team members.

Finally, our findings need to be understood within the context of a highly cooperative environment of *Portal 2* where there is no competitive element. The presence of competition, either internal or external, may change the communication content and dynamics. To be able to design systems that encourage positive interactions, good teamwork and minimise toxicity, all potential input sources (i.e., individual characteristics, task characteristics and communication modalities) need to be investigated. Nonetheless, our findings on textual communication dynamics in Portal 2 shows that in this context, where teams are comprised of strangers in a one-off interaction, communication tends to be highly task-oriented and positive.

4.8 Conclusion

To better understand how ad hoc teams of strangers in digital games cooperate effectively, we investigated team communication. In contrast to the literature, we find that communication is negatively related to performance. Nonetheless, communication is an important factor of team performance above and beyond prior experience or expertise, accounting for 13% in variance explained. This suggests that teamwork between strangers can be improved by designing systems that facilitate more efficient communication. Team communication between strangers also tends to be more task-oriented. While in contrast to prior research on the communication

content in digital game groups and teams, it more closely reflects communication in temporary teams in competitive cooperative games, zero-history computer-mediated work groups, and real-world ‘swift starting action teams’ like flight crews and crisis teams. Our study sheds light on the potential mechanisms through which communication influences performance and possibly, the development of social ties in teams of strangers. It moves us closer to understanding how team communication might develop cohesive, high performing teams.

Chapter 5: Analysing team communication data in fast-paced ad hoc teams

After piloting the communication analytics method on two-person teams in *Portal 2* (Chapter 4), we conducted a larger study on teams in the competitive game *League of Legends*. In this study, we analysed team voice communication data. The findings indicate a positive relationship between communication frequency and performance. If this relationship is causal, it suggests that a high frequency of voice communication is beneficial for cohesion but not for team performance. This supports the findings from Chapter 4.

Qualitative analysis of the interaction between team members suggests that cohesive teams may be differentiated by their communication sequences. The findings imply that the volume of communication in a team and the interactions between team members are indicators of cohesion.

Part of this research project was conducted during my research exchange at the HCI Games Group at the University of Waterloo, Canada under the Globalink Doctoral Exchange Scheme.

This chapter was published at CHI PLAY 2022 and won the Best Paper Award.

> Tan, E. T., Rogers, K., Nacke, L. E., Drachen, A., & Wade, A. (2022). Communication Sequences Indicate Team Cohesion: A Mixed-Methods Study of Ad Hoc League of Legends Teams. *Proceedings of the ACM on Human-Computer Interaction*, *6*(CHI PLAY), 1-27.

I am the first author of this paper. I designed the research study and performed and managed the research team involved in data collection, data cleaning and data processing. I analysed the data and led the paper writing with my co-authors.

Additional data analysis has been included in the Appendix (Section 7.2).

5.1 Abstract

Team cohesion is a widely known predictor of performance and collaborative satisfaction. However, how it develops and can be assessed, especially in fast-paced ad hoc dynamic teams, remains unclear. An unobtrusive and objective behavioural measure of cohesion would help identify determinants of cohesion in these teams.
We investigated team communication as a potential measure in a mixed-methods study with 48 teams (n = 135) in the digital game *League of Legends*. We first established that cohesion shows similar performance and satisfaction in *League of Legends* teams as in non-game teams and confirmed a positive relationship between communication word frequency and cohesion. Further, we conducted an in-depth exploratory qualitative analysis of the communication sequences in a high-cohesion and a low-cohesion team. High-cohesion is associated with sequences of apology→encouragement, suggestion→agree/acknowledge, answer→answer, and answer→question, while low-cohesion is associated with sequences of opinion/analysis→opinion/analysis, disagree→disagree, command→disagree, and frustration→frustration. Our findings also show that cohesion is important to team satisfaction independently of the match outcomes. We highlight that communication sequences are more useful than frequencies to determine team cohesion via player interactions.

5.2 Introduction

Cohesion is defined as the shared bond or attraction that drives team members to want to work or play together and stay together [13]. Cohesion has task and social dimensions and is critical to effective team functioning [10], [11], [13]. The interactions between team members give rise to this emergent affective state, which is shaped by the context over time and manifests as a team-level phenomenon [27], [30], [74]. Without a sense of cohesion in the team (caused by dislikes, disinterests, or other

reasons), members are less likely to engage in team-oriented behaviours (i.e., ‘teamwork’) that enables a team to function effectively. As such, cohesion has been linked to better team performance, satisfaction, and members’ intention to remain in and return to the team. These findings stem from domains including sports [1], [11], defence [22], [91], and business [26], [223].

Despite much research on cohesion, we do not know what we can do to foster team cohesion. Empirical evidence of team cohesion predictors is scarce [13], [224]. This knowledge gap has been attributed to measurement methods (i.e., validated measures of cohesion are almost exclusively questionnaires), and a lack of longitudinal studies [30], [40], [224]. These limitations also make it difficult to tease apart the cyclical relationship between cohesion and performance [74]. The current limitations of cohesion measurement methods have made it particularly difficult to examine the impact and predictors of cohesion in fast-paced, ad hoc, dynamic teams—also known as swift starting action teams (STATs)—that work in high-stakes environments (e.g., surgical teams or emergency response teams) where team success is critical. Identifying alternative, unobtrusive behavioural measures of cohesion is paramount to understanding how individual interactions give rise to team-level phenomena like cohesion and how one might foster and shape these positive team-level phenomena [30], [40].

Team-based digital games allow us to observe ad hoc teams in action and generate an easily accessible record of interactions between players throughout the lifetime of the team (i.e., for the game session). Parallels have been drawn between the team context and task demands of digital games STATs and real-world STATs [59], [58]. The evidence that teamwork skills obtained through team-based digital games generalise to real-world STATs—despite games being a playful environment—is growing [59], [60]. Thus, cohesion—found to be critical to effective teamwork in real-world teams—is likely equally important to teamwork in digital game teams. Multiplayer team games address existing and emerging issues of team performance research. Researchers like Shneiderman [225] and Dyck et al. [226] echo this and have described games as a driving force of HCI research, for example, in the context of

facilitating situation awareness, and others who have referred to games as “a perfect test-bed for HCI explorations” [227].

In the present study, we investigate *team communication*. Team communication, for the purposes of our study, is made up of word frequencies, content/category frequency, and communication sequences. We investigate those measures as proxy behavioural indicators of cohesion because effective communication is critical in STATs [228], [129], [108]. We first establish the relationship between cohesion, performance, and satisfaction demonstrated in other domains [91], [13], [10] in *League of Legends* [68] STATs. We subsequently find that word frequency—but not content (e.g., communication category) frequency—is related to cohesion. Finally, we conducted an in-depth qualitative analysis of communication sequences in two losing teams—one with high cohesion and one with low cohesion—to identify potential communication sequences that may indicate cohesion while controlling for performance. We found differences in communication sequences between the high-cohesion and low-cohesion team. These sequences require further investigation in future work to be verified, validated, and generalisable. Nonetheless, the qualitative analysis indicates potential differences in communication patterns between high- and low-cohesion teams. The present study was conducted on 48 *League of Legends* STATs fully composed of strangers (n = 135), using a combination of self-report, behavioural data, and in-game data.

Our contributions to the HCI-focused game research include: (1) adding digital games as a new domain of inquiry to the cohesion literature, (2) showing that cohesion is important to both team performance and satisfaction in *League of Legends* STATs and that team cohesion can exist despite poor team performance, (3) providing initial evidence of communication frequency as a proxy behavioural indicator of cohesion, (4) introducing and showing the value of an underutilised methodology—sequence analysis—for investigating communication in digital games, and (5) identifying communication sequences that may determine different levels of cohesion which forms a basis for future research.

5.3 Related Work

5.3.1 Team Cohesion Definition, Conceptualisation, and Measurement

Definition and Conceptualisation

Team cohesion is conceptualised as an affective team-level phenomenon defined as the shared bond or attraction that drives team members to want to work together and stay together [11]–[13]. Importantly, as an emergent team-level phenomenon, team cohesion does not exist before a team is formed and comes into existence only after team members have interacted. Cohesion has a task dimension that reflects a team's shared attraction or commitment to the team task or goal, and a social dimension that reflects a team's shared interpersonal attraction or liking to each other. Cohesion is one of the most widely-studied team states because it is thought to be critical to effective team functioning [10], [12], [13], [18]. Cohesion has consistently shown positive relationships with performance in sport, military, business, and academic teams (see [10] for examples). Beyond performance, members of teams with higher levels of cohesion report greater satisfaction with the team [17], [229], more positive mood responses [230], higher team morale [231], and higher intention to return to the team [1], [2]. Cohesion is not only important to team performance, but leaves members feeling satisfied and can increase team member retention.

With the exception of a handful of studies [67], [167], [168], [232], [233], team cohesion has received very little research attention in digital games. Studies that have incorporated team cohesion, have either done so indirectly [232], or without conceptualising it in line with the main body of cohesion literature [167], [168]. For example, Buchan and Taylor [167] conducted a qualitative analysis (grounded theory) on factors that contribute to optimal team play in competitive team-based games through the lens of cohesion. However, the authors did not define cohesion explicitly, making its conceptualisation unclear. This makes it difficult to contextualise their findings within the wider cohesion literature. On the other hand, Kwak and colleagues [232] indirectly investigated the cohesion-performance relationship in *League of Legends*. The authors framed one of their research questions around the construct of

cohesion found in sports research (in line with the cohesion literature) but did not explicitly test the relationship between cohesion and performance. Instead, they inferred that team cohesion is moderated by negative 'toxic' behaviours exhibited by members (dysfunctional behaviours that are detrimental to the team) such that it lowered team cohesion, which in turn lowered team performance [232]. Similar to the non-games literature, cohesion is thought to create positive experiences despite negative outcomes [166]. As noted by a participant in Tyack et al.'s [166] study:

> "A positive game [occurs when] even if the game is bad, everyone works as a team".

This sample of studies suggest that cohesion is also important to team performance and positive subjective experiences for teams in the digital games domain.

Measurement Issues and Antecedents

A critical gap in our knowledge of team cohesion is its predictors. There is little empirical evidence on antecedents of cohesion despite the large body of work on cohesion and its positive effects. This is largely due to how cohesion has been measured and how studies have been designed [30]. Historically, team cohesion has been measured exclusively using questionnaires and mostly using studies with cross-sectional designs [40]. Questionnaires are intrusive, require ongoing activity to be suspended for members to reflect, can be biased or risk responses being affected by the delay between the questions and the experience, and may not always be suitable for certain teams [40], [224]. Although this method has led to considerable progress on our understanding of cohesion and its consequences, it has been difficult to capture the full picture of the construct. Moreover, current measurement methods are not suitable for investigating cohesion in fast-paced, dynamic teams working in high-risk environments (i.e., STATs) where successful team performance is critical. Therefore, it is necessary to identify proxy indicators that can provide an unobtrusive behavioural measure of cohesion [13], [30], [40], [224].

There has been a recent increase in studies investigating alternative measures of cohesion. Some have used features of conversational behaviours (such as turn taking) from a meeting to estimate team cohesion [48], while others have combined conversational behaviours with proximity and frequency of interaction metrics obtained from wearable sensors to investigate cohesion in space exploration teams [45]. As per Kozlowski and Chao [30], these studies suggest that "digital traces of meaningful behaviour that are frequent, ongoing, unobtrusive, and process-oriented offer an extraordinary opportunity to gain insights on emergent phenomena and team dynamics", such as team cohesion. It should be noted, however, that while the ultimate goal is to obtain reliable and valid unobtrusive measures, such alternative techniques must still be supplemented by traditional approaches (i.e. a cohesion questionnaire) in order to assess construct validity [224].

Our study contributes to this process by using an environment where digital traces are abundant: *digital games.* Digital games may be especially valuable for identifying proxy indicators and predictors of cohesion in STATs. STATs are prominent in competitive team-based digital games, with hundreds of millions of people all over the world engaging in the rapid formation of teams and engaging with each other in highly complex team task environments [58], making this an ideal environment for investigating cohesion (and other team performance measures) at scale. For this reason, we use STATs in the competitive team-based digital game, League of Legends [68] to identify alternative, proxy indicators of cohesion.

5.3.2 Team Communication in Swift Starting Action Teams

One factor that has been identified as a potential antecedent and proxy indicator of cohesion is team communication [234], [69], [89], [195]. We acknowledge that there are other factors that may influence cohesion, such as team composition [75], [89], [235], however, given the focus of the present study – to identify behavioural indicators of cohesion – we chose to focus on observable behaviours via team communication. A meta-analysis of 72 studies found that communication (termed ‘information sharing’) was correlated with team performance (ρ = .42) and cohesion (ρ = .20) [69].

Cohesion seems to be influenced by a high communication frequency – it was more strongly related to the extent that teams shared information regardless of the distribution of commonly held information compared to the extent that teams shared information that is uniquely held by each member [69].

Team communication is defined as “an exchange of information, occurring through both verbal and nonverbal channels, between two or more team members” [107]. In digital games, nonverbal channels include text chat, ‘pings’ (attention-focusing, location-based, semantically imbued icons), ‘automated messages’ (predefined messages, announcements, or responses that players select with a click of a button), and annotations [180], [181], [194]. Players use nonverbal channels for multiple task-related functions such as planning, and coordinating, and social-related functions like expressing frustration [181]. This is in line with the notion that team communication serves multiple task and social functions [236]: it conveys information, establishes interpersonal/team relationships as well as predictable behaviour and expectations, maintains attention to the task and situational awareness, and is a management tool. For our study, we focus on verbal team communication because this allows us to draw from and connect to the literature on non-game teams where verbal communication is most common.

Communication has been a key area of focus for STATs because early research on accidents and incidents in the aviation industry found that over 70% of all accidents were attributed to communication problems [111], [237], [238]. STATs are characterised by unfamiliar members. They have stable roles but ad hoc membership, require immediate performance under time-pressured high risk environments, and disband once the task is over [129] (e.g., military units, emergency response teams, crisis teams, surgical teams). STATs must communicate effectively to perform well immediately in high risk environments [129]. As a result, extensive research has been conducted to identify effective communication behaviours that can be used to improve team performance [236]. This includes identifying how much should be said (i.e., word frequency), what should be said (i.e., content) and how messages should be conveyed (i.e., the interaction pattern or sequences). For example, Sexton and

Helmreich [111] investigated differences in word frequency, frequency of first person plural words (i.e., we, us, our), and frequency of teamwork-oriented words (e.g., try, effort, goal), on its relationships with task load and performance in commercial cockpit crews and found these communication variables to correlate with performance and error rates. One of the main findings from this research domain is that incorporating the analysis of communication sequences, or the flow of information between members, provides more comprehensive insight into how communication influences team success in STATs [71], [236]. An early study investigating problems in cockpit communications found that crews with a higher communication frequency tended to perform better and, in particular, those who exchanged more information about flight status committed fewer errors [73].

Similarly, communication sequences differentiated between high- and low-performing military aviation crews, but these crews could not be differentiated by their communication category frequencies (e.g., the extent that crew members asked questions, provided acknowledgements, or engaged in non-task related communication) [228]. These studies show that communication sequence analysis provides additional data on the nature of effective team processes that cannot be accessed via simple frequency counts. Today, sequence analysis is a widely used method to investigate effective communication protocols in real-world STATs including medical teams [112], [120], nuclear plant crisis crews [51], [239], and aviation crews [52], [72]. Moreover, findings from communication research in military and aviation communities have helped improve team effectiveness in the medical community, for example, by identifying the importance of closed-loop communication (a communication strategy that ensures messages are received and interpreted as intended) in reducing misunderstandings and patient incidents [122], [124].

This implies that research methods, insights, and interventions uncovered in swift starting aviation crews apply to other STATs domains so long as the team characteristics and teamwork demands (i.e., rapidly formed teams of strangers that have to immediately perform in high stakes, time-sensitive situations) are similar. As such, our study investigates the role of communication and cohesion in STATs in the

digital games domain. We use the game *League of Legends* [68] because it offers a naturalistic complex team environment that mimics the task environment of real-world STATs. Additionally, we investigate a specific type of team in the game – ad hoc teams of strangers (herein referred to as '*League of Legends* STATs') because these teams have similar team characteristics as real-world STATs. These types of teams are not only common in *League of Legends* [68] but in many online competitive team games [240], [166]. In line with communication research in the STATs literature, we supplement communication frequency analysis with communication sequence analysis to investigate how communication influences team cohesion *in League of Legends* STATs.

5.3.3 League of Legends

In the present study, we use the standard version of the game ('Summoner's Rift') where two five-player teams start on opposite ends of the map and try to destroy the other team's base while protecting their own (Figure 16). *League of Legends* [68] utilises a matchmaking algorithm to create matches consisting of players of approximately equal skill level to ensure that both teams have an equal chance of winning [241]. The match ends when one team has successfully destroyed the centre of the other team's base (the 'Nexus'). A match typically lasts 30 minutes [131]. During the match, players control units (known as 'champions') that have certain abilities. Teams defend their Nexus with their own champion, non-player units (called 'minions'), and defensive structures (buildings that deal damage known as 'towers' and 'inhibitors'). Minions follow a set path (known as a 'lane') towards the main enemy buildings leading up to the Nexus and attack nearby enemies.

There are three main paths known as 'Top', 'Mid' and 'Bot', that correspond to the top part, middle part, and bottom part of the map respectively (Figure 16). The area between these paths is known as the 'Jungle'. In each team, four players typically distribute themselves along the main paths and one player will patrol the Jungle looking for ambush opportunities. When players are dispersed across the map, they have a limited field of vision and cannot see what is going on in remote locations. This

makes information more distributed [242] which in turn creates a need for players to actively communicate changes in their environment to the team in order to coordinate actions and avoid ambushes.

Throughout the match, players gain ‘gold’ (used to buy items that strengthen a player’s champion) and ‘experience’ (allows players to unlock and increase the strength of their champion’s abilities) when they kill minions, enemy champions, and enemy buildings. Players can also gain ‘gold’ and ‘experience’ from assisting a kill (known as ‘assists’). In the middle of the map are neutral team objectives (powerful neutral monsters known as ‘Dragon’, ‘Herald’ or ‘Baron’) that give bonuses to the team that achieves them. These objectives are usually difficult for a single player to complete thus requiring teamwork. The interaction between individual skill, environment constraints (i.e., limited field of view), and teamwork requirements make *League of Legends* [68] a complex game that poses challenging teamwork demands. Not only do players recognise the importance of teamwork to success [174], but effective teamwork is becoming an even more important factor in *League of Legends*– the game’s developers have been introducing mechanics that increase the impact of effective teamwork over individual performance [243], making it more difficult for a team to win a match without cooperation.

Figure 16 League of Legends classic map.

League of Legends classic map. One team starts at the bottom left corner of the map (Blue Team Nexus) and the other team starts at the top right corner of the map (Red Team Nexus). Players distribute themselves between the Top Lane, Mid Lane, Bot Lane, and Jungle, and typically meet their opponents in the main paths (Top Lane, Mid Lane, and Bot Lane). Team objectives generate every few minutes throughout the game and give powerful bonuses to the team that achieves them. The match ends when a team's Nexus is destroyed. Image via Riot Games *[68]*

5.3.4 Challenges to Teamwork in *League of Legends*

In *League of Legends* [68], players have unique roles, complementary abilities, are geographically dispersed with limited field of view, and have to compete with opponents over advantageous team-oriented objectives – these game mechanics are common in many cooperative games and are thought to foster cooperation and other teamwork behaviours between players [242], [244]. However, there is no guarantee that such behaviours will actually occur. In *League of Legends* STATs, players find it challenging to effectively work with strangers, and it is common for such teams to be dysfunctional and leave players feeling frustrated [166], [240], [245]. Similar to real-world STATs, *League of Legends* STATs that are able to quickly learn how to effectively communicate and coordinate their actions while managing conflict are more likely to be successful.

However, the lack of familiarity between team members poses challenges to predicting teammate behaviours and coordinating actions [166], [240]. This may be exacerbated by a lack of a shared mental model, defined as "a consensual understanding of their task, team, and situation" [246]. When team members lack this shared model, this may lead to disagreements which if unresolved would lower cohesion and ultimately result in poor performance. This is a common phenomena; Kou et al. [177] found that 'toxic behaviours' (i.e., negative, dysfunctional behaviours that are detrimental to a team) in ad hoc teams of strangers are often a result of difficulty resolving conflicts such as disagreements over moment-to-moment objectives or differences in perception of a team's chance of winning. In contrast, Johnson et al. [174] found that players felt cohesive when the team had unity and team members conformed to strategies. Moreover, teamwork was identified as an important motivator for continued play [174] while 'toxic behaviours', on the other hand, reduce player retention [247].

This implies that if *League of Legends* STATs are unable to exhibit the team processes that enable effective teamwork, it not only impacts performance, but the subjective experiences of playing in the team, such as satisfaction. Although satisfaction is not a critical outcome in real-world STATs, identifying how to increase satisfying player experiences while reducing negative, 'toxic' experiences is important for game developers since it influences player retention. For these reasons, identifying proxy behavioural measures and predictors of cohesion has important implications for both real-world STATs and digital game STATs.

There is some evidence on how to foster cohesion in *League of Legends* STATs based on qualitative studies. Kou and Gui [64] found that players try to actively communicate with their teammates in order to develop a shared understanding of the changing environment, and try to maintain a positive atmosphere with positive sentiment and encouragement. Using grounded theory, Buchan and Taylor [167] found that team communication, specifically, having a relatively high level of communication, using voice communication platforms, and keeping communication

friendly, was key to enabling optimal team play and cohesion when teammates are strangers. These studies highlight the role of team communication in fostering team cohesion but do not explicate the relationship to identify how the communication (i.e., the interaction) between team members actually gives rise to cohesion. To understand this relation in greater depth, an investigation of team communication behaviours is required. In doing so, we can identify cohesion-building behaviours that may benefit both real-world STATs and digital game STATs.

5.3.5 Research Questions

Our goal is to address the critical gap in the literature on the lack of antecedents of cohesion. We do so by investigating team communication as a proxy indicator of cohesion, specifically within the context of online swift starting *League of Legends* [68] teams of strangers. A primary motivator of the study is to investigate whether team-based digital games can be used as a test bed to study team cohesion. To do this, we needed to establish whether cohesion is related to performance, and satisfaction in digital games, as shown in other literature outside the games domain (RQ1 and RQ2).

This will enable us to contextualise our findings within the wider cohesion literature:

RQ1: Can we observe the cohesion-performance relationship in digital games?
RQ2: Can we observe the cohesion-satisfaction relationship in digital games?

Once the relationships have been established, we wanted to investigate whether communication frequency can be used as a proxy indicator of cohesion in digital games (RQ3):

RQ3: Is communication frequency related to team cohesion in digital games?

Although communication frequency is a widely used metric, research on communication in swift starting aviation crews suggests that other metrics, such as communication sequences, may provide greater insight into how STATs become effective. Therefore, an exploratory research question is whether communication

sequences can also be used as proxy indicators of cohesion, and if so, whether there are specific sequences that might warrant future research (RQ4):

> **RQ4:** Are there potential communication sequences that could be explored as indicators of team cohesion in digital games for future work?

5.4 Method

Encouraged by the literature to supplement cohesion questionnaires with alternative measures, we employed a mixed-methods approach to address the research questions. Correlational analyses were used to analyse the relationships between cohesion, performance, satisfaction, and between cohesion and communication frequency in ad hoc League of Legends teams. The interactions between team members were then categorised using an adapted coding scheme from Zijlstra et al. [216], and qualitatively analysed using Bakeman and Gottman's [248] Lag Sequence Analysis (LSA) – these methods are discussed in more detail in the Data Analysis section. We present a case study comparing two teams detailing our findings from the qualitative approaches.

5.4.1 Participants

135 participants were recruited from the *League of Legends* Reddit group [249]. Participants were 18 years old and above, played *League of Legends* [68] regularly, played on the European or North American server, and ranked Silver, Gold or Platinum. A player's rank is a proxy indicator of their skill level based on their win rate. To increase the likelihood of getting a high number of participants of similar skill levels, only these ranks were included because they were the most populated ranks during the study period (see February 2020 distribution in [250]). Participants were assigned to a team based on their rank, server, role preference, and availability. Within each rank, there are five sub-ranks. The maximum rank difference in each team was two sub-ranks to control for the effect of skill disparity to the best of our ability.

There were 48 teams in total – 33 teams where only three (out of five) players were study participants, and 15 teams where all five players were study participants. In teams where only three (out of five) players were study participants, the remaining two players were randomly assigned from the game's matchmaking system. The additional players were not in the voice communication server and were not in voice communication with the participants. We acknowledge that this may affect the game play, however, there are other in-game communication tools (e.g., pings, text chat, short automated messages) that players typically use to communicate when voice communication is not present [180]. We also acknowledge that it may limit our analysis and subsequent findings on the relationship between communication and cohesion. Often, three person teams were a result of players dropping out last minute or not confirming their attendance in time. At the risk of losing study participants due to long wait times for finding a team and given how resource intensive team research is, we chose to proceed with three person teams as well. This study received ethical clearance from the local institution.

5.4.2 Materials and Measures

Voice Communication

Players in *League of Legends* often communicate by voice over Discord: a voice and video conferencing application designed specifically for games [172]. Here, we initiated and recorded the Discord voice communication and the game play. Team voice communication was then transcribed (described in more detail in Section 5.5.3). We used two measures of communication: communication frequency and category frequency. Communication frequency was operationalised as the mean number of words generated per minute (mean WPM) for each team. The mean WPM was calculated by first obtaining the number of words generated in each minute of the game (words per minute). The words per minute for each minute was then summed and divided by the number of minutes to obtain a mean WPM score. This allowed us to obtain a standardised measure of communication frequency across teams with

different match durations. Category frequency was operationalised as the mean number of instances generated for each category per minute (mean CPM) for each team using the same calculations for mean WPM.

Team Cohesion

Team cohesion was measured using a six-item questionnaire that has shown good reliability and is suitable for use in ad hoc teams [14], [98]. The questionnaire contains the two dimensions of cohesion: task cohesion (e.g. “Our team was unified in its task focus.”) and social cohesion (e.g. “Our team members had good relationships with one another.”), and was answered on a seven-point Likert scale (1 = strongly disagree to 7 = strongly agree). Coefficient alphas were computed for the scale and showed good reliability, α = 0.90 (CI = 0.88 - 0.92). Participants answered the questionnaire individually. Individual cohesion scores, i.e., self-reports of perceived cohesion of the teams, were aggregated to the team level, because these showed high within-group agreement, indicating shared perceptions of cohesion (rwg = .90; [251], [252]).

Team Satisfaction

Team satisfaction was measured using a four-item questionnaire, adapted from the Athlete Satisfaction Questionnaire (ASQ; [253]), which has been used to investigate the cohesion-satisfaction relationship in sport teams and shows good reliability [19], [229]. It contains 15 dimensions of athlete satisfaction; in the current study, only the ‘team integration’ dimension was used. This dimension is defined as “satisfaction with the extent to which members of the group contribute and coordinate their efforts toward the accomplishment of the group’s task” (p.133) [253] . The questionnaire was answered on a seven-point Likert scale (1 = not at all satisfied to 7 = extremely satisfied). The scale demonstrated good reliability, with an alpha coefficient of α = 0.91 (CI = 0.89 - 0.93). Participants answered the questionnaire individually without discussion with their teammates. Individual satisfaction scores were aggregated to the team level following high within-group agreement, indicating shared perceptions of satisfaction (rwg= 0.92; [251], [252]).

Performance

Team performance was operationalised as the outcome of the match (i.e., win or lose). While there are multiple ways to measure performance, we wanted a metric that reflected a team-level outcome rather than aggregations of independent individual-level outcomes. For example, team-level “gold per minute” (the amount of gold a team generates per minute via killing minions or opponents) or team-level “kill per minute” (the number of kills the team gets via killing opponents) interacts with individual skill. However, the match outcome is much more dependent on the extent of teamwork a team exhibits – individual gold/kill per minute is not enough to sway the outcome. Developers of *League of Legends* [68] are actively focusing on reducing the influence of individual performance on match outcome, and introducing mechanics that incentivise teamplay to close a match [243]. For this reason, performance was operationalised as the match outcome.

5.4.3 Procedure

After being assigned to a team, participants were invited to join a custom private server on Discord [172]. Participants were required to join the voice communication channel to communicate with their team. After the team was briefed on the study procedure, the team queued for a *League of Legends* [68] match in the ‘Ranked Flex’ mode (the only game mode that allows full teams of five to queue up for a match against another five-person team). For the three-person teams, the additional two players were randomly assigned by the game’s matchmaking system. Hence these teams consist of three players who were study participants and two players who were not. Only study participants were in the custom private server on Discord. Once a match was found, the team’s gameplay and voice communication were recorded. The participants were left to play the match uninterrupted. After the match ended, the outcome was recorded by the study investigator and participants were asked to individually complete the team cohesion and satisfaction survey. Participants were then debriefed and thanked for their participation.

5.5 Data Analysis

In this section, we describe the analytical methods that were used to answer each research question. The first two sections are quantitative investigations of our research questions relating to cohesion, performance, and satisfaction (RQ1 and RQ2 in Section 5.5.1) and relating to communication and category frequency (RQ3 in Section 5.5.2). The final section (5.5.3) describes how the transcripts were coded qualitatively for our exploratory investigation of communication sequences in a high- compared to low-cohesion team, and how we applied Lag Sequential Analysis to these codes to answer RQ4. Due to its exploratory nature, this section should be considered a case study.

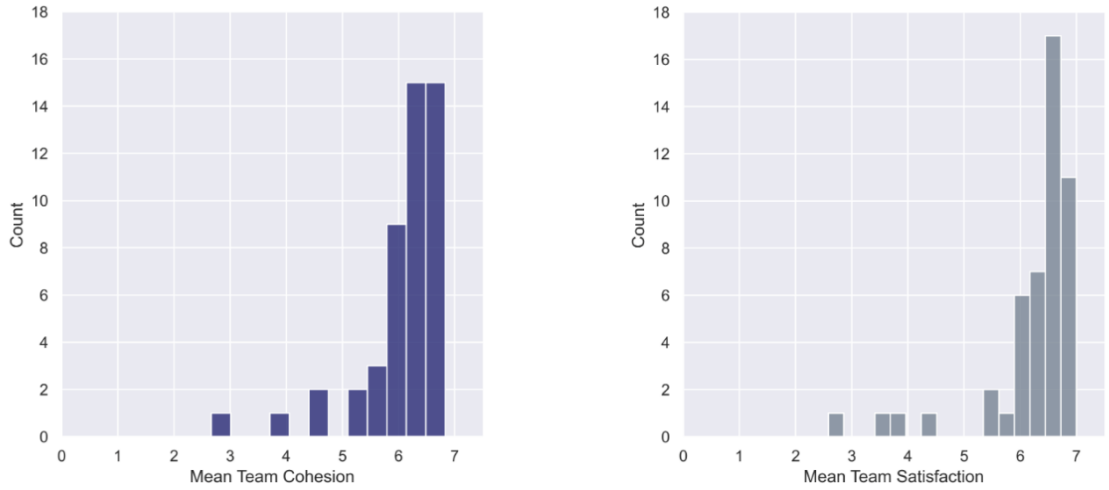

Figure 17 Distribution of team cohesion and team satisfaction.

Distributions of team cohesion (left) and team satisfaction (right) across the sample were strongly left skewed. A Shapiro-Wilk test of normality showed that the distribution of team cohesion (W = 0.73, p < .001) and team satisfaction (W = 0.66 p <.001) significantly departed from normality.

5.5.1 Establishing Cohesion-Performance and Cohesion-Satisfaction Relationships in Digital Games (RQ1 and RQ2)

To confirm whether cohesion is important for teamwork in digital game teams, we first investigated whether cohesion exhibited similar relationships with performance

and satisfaction as have been observed in non-digital game teams. Team cohesion scores and team satisfaction scores were not normally distributed: teams generally reported high levels of cohesion, M=6.07, SD=0.7 and satisfaction with the team, M=6.25, SD=0.88 (see Figure 17). As the data were not normally distributed, a Kendall's Tau [254] partial correlation was used to analyse the relationships between mean team cohesion, performance (match outcome), and mean satisfaction with the team. The p-values were corrected using a post-hoc Bonferroni [255] adjustment to correct for multiple comparisons.

5.5.2 Investigating the Relationship Between Communication Frequency and Cohesion (RQ3)

We then investigated whether the communication frequency-cohesion relationship observed in non-digital game teams [69] could also be found in our digital game teams. A Kendall's Tau [254] partial correlation was conducted to investigate the relationships between communication frequency (mean WPM) and team cohesion. Match outcome was included in the analysis since there are several meta-analyses indicating a positive correlation between communication frequency and performance [69], [107]; a post-hoc Bonferroni correction [255] was used to adjust for family-wise errors. Since the literature suggests a relationship between communication content/quality with cohesion [69], [70], we also checked for significant relationships between specific communication categories and team cohesion in our study.

5.5.3 Exploratory Analysis of Communication Sequences: A Case Study (RQ4).

We wanted to investigate whether other measures of communication could provide further insight into how communication influences cohesion. In particular, as addressed in the Background section, research on communication in STATs has highlighted the value of investigating communication sequences in addition to communication frequencies. Communication sequence analysis can provide additional insight on the interactions between members that lead to different team outcomes [52], [112], [121], something that simple frequency analysis cannot capture.

As such, we applied Lag Sequential Analysis (LSA), a type of sequence analysis technique to the codes developed and applied to the transcripts via content analysis [115], [256], [257].

Transcribing Speech to Text.

The audio files were first automatically transcribed using the Otter.ai.
speech-to-text engine. A dictionary of League of Legends champion names was provided to help improve the accuracy of the automated transcription process. The transcriptions were then corrected manually by human transcribers who were domain experts (i.e., regular League of Legends players). The transcribers were instructed to correct the speaker identity (coded by player, e.g., 'Player 1 Team 1'), timestamp of start of speech, and words spoken. When there was cross talk (i.e., multiple players talking at the same time), the transcribers were instructed to transcribe as much as could be heard; ambiguous speech was noted '(inaudible)'.

Developing the Coding Scheme.

The communication category coding scheme was adapted from Zijlstra et al. [52] (p.761) and focused on categorising statements/sentences rather than individual words. They used their coding scheme to investigate early interaction patterns in ad hoc aviation flight crews and its relationship with team effectiveness [236], which is based on previous research on aviation crew communication and coordination behaviours [236]. This coding scheme was chosen for the present study because of the similarity of the team context and task demands.

Like Zijlstra et al. [52], we use ad hoc teams, with members who are unfamiliar with each other and who have no prior experience together but have to engage in immediate task performance. The coding scheme was then adapted to fit the League of Legends context: seven new communication categories were added to account for this based on the domain knowledge and experience of the coders. There were 17 communication categories in total; see Table 6 for the original codes from Zijlstra et al. [52], and Table 7 for the additional codes based on the lead researcher's domain knowledge.

Table 6 Coding scheme.

Content Type	Description	Example(s)
Command	A specific request or demand for action. Command statements give explicit direction.	"Be careful."; "Focus on Jhin."
Observation	Recognising or noting a fact or occurrence. Observation statements bring attention to occurrences and changes in the environment or situation. These statements do not contain an analysis on the situation.	"Mid missing."; "It's warded."; "I'm up in two minutes."
Suggestion	Giving or asking for a recommendation for action. Suggestion statements usually include "can", "could" and "should".	"We should look to Drake."; "I could help you ward if you like."
Questions/ Inquiry	Requesting for information or asking for confirmation. Question statements do not contain recommendations.	"Has Ezreal used his ultimate?"; "Is there a ward there?"
Answer	Any response to a question. Includes "yes/no" responses as confirmation to questions.	"No, he hasn't used his ult"; "Yes, there's a ward here" (in response to question)
Disagreeing	Giving a response that is not in agreement with, or rejects a previous statement or suggestion. This does not necessarily require an explicit "no".	"No I don't think we should do that"
Humour and Taunting	Laughter, clearly humorous remarks, or taunting.	"Hehe pepega."; "Oh you want to dance Morgana (directed to enemy)?"
Anger and Frustration	Statements that exhibit feelings of anger or frustration. These can be directed towards the team, teammate, enemy, or self.	"I don't know what our Support is doing?"; "Ugh his ult is so annoying!"; "I'm inting."
Apologies and Remorse	A remark that expresses sorrow or regret for prior action.	"My bad."; "I shouldn't have done that."
Non-Work or Social	Social non-task communication. Includes statements relevant to *League of Legends* that do not contribute to completing tasks in the immediate match.	"Season 11 Lulu was the best."; "My mouse has stopped working."

Coding scheme for communication content types from Zijlstra et al. [52] with examples from our data. We made minor adjustments: 'Humour and Taunting' was originally labelled 'Laughing' and 'Anger and Frustration' was originally labelled 'Anger'.

Table 7 Coding scheme (cont.).

Content Type	Description	Example(s)
Sharing Intention	Supplying information about an action intention, including a preference for something. These statements do not request input from anyone else, and do not contain evaluation or analysis of situation.	"I think I'd prefer to stay bot"; "I'm coming."
Agreeing and Acknowledgement	Statements showing agreement or acknowledgement of a command or suggestion for action.	"Okay."; "Yeah."
Opinion, Analysis, and Evaluation	Statements of evaluation, analysis, predictions, or speculation. These statements can include reasoning for actions. Includes an individual thinking out loud their evaluation or analysis rhetorically.	"I need scuttle crab to reset"; "If you kill Camille here we can shove mid."
Encouragement	Statements that encourage, celebrate, or comfort a teammate(s).	"That's unfortunate."; "Unlucky."; "It's okay."
Thanks and Welcome	Statements of thanks and response to thanks.	"Thanks."; "No problem."
Expressing Emotions/Feelings	Verbal expressions of emotions or feelings in response to or towards an event	"How disappointing."; "Oh oh oh!"
Miscellaneous	Statements that do not fall under any other category or are ambiguous due to transcription limitations.	"They're (inaudible)"

Description of codes added to Zijlstra et al.'s [52] coding scheme to reflect the League of Legends domain

Coding the Data.

The transcriptions were coded by four trained coders, three with domain knowledge (regular League of Legends players) and one without. Each transcript had two coders – the lead researcher was the first coder for all 48 transcripts. For the second coder, 24 transcripts were assigned to the second most experienced coder, and the remaining two coders were assigned 12 transcripts each. The data were coded iteratively: after a subset of the transcripts had been coded (approx. 2-4), the coders met to discuss any ambiguities in the sentences and communication category definitions. The coders were then allowed to recode their transcripts based on the updated definitions.

Since sentences may contain multiple communication categories, coders were instructed to assign up to two codes per sentence. If a sentence was assigned two codes, the common code between the two coders became the primary code because that was the code that had consensus. Fleiss' kappa [258] showed good agreement between the coders, κ= 0.894.

Lag Sequence Analysis.

LSA has been used to investigate how team members of high-stakes teams (e.g. medical teams and nuclear plant crews) interact – operationalised as communication sequences – to solve problems under evident time pressure [112], [239]. Specifically, LSA analyses temporal patterns in sequenced data to identify chains of events [248], [259]. It determines how likely one event follows another event (in our study, 'events' refers to categories of communication statements). For example, Kolbe et al. [260] found that performance in ad hoc anaesthesia teams could be predicted by how often nurses spoke up. Using LSA, they showed that when nurses spoke up, this led residents to provide clarifying information on the procedure or to reevaluate their decision. Kolbe et al. [260] thus were not only able to identify 'speaking up' as a predictor of performance but by using LSA, gained insight into how speaking up affects performance. Sequence analysis methods, in general, have been successfully used to investigate effective communication patterns in STATs [71], [120], [239]. For this study, LSA was used in an exploratory manner to identify communication sequences that might be used to differentiate between levels of cohesion, performed in R [261] via the 'sequential' function of the 'LagSequential' package [262].

The results of LSA are transitional probabilities, z-scores, p-values of z-scores, and Yule's Q [248]. Transitional probabilities are conditional probabilities that indicate that a certain event B will occur given the occurrence of event A (the likelihood that A triggers B). Z scores indicate which transitional probabilities deviate significantly from their expected values; a significant positive z score indicates that event A is followed significantly more often by event B. In contrast, a significant negative z score indicates that event A is followed significantly less often by event B. Importantly, the z score tells us which sequences occur significantly more than chance and the direction of the sequence, but not the strength of association; Yule's Q reflects the effect size of the sequence.

Sequences are considered statistically significant at the .05 level if the z score was larger than 1.96 absolute, in line with Bakeman and Gottman [248]. LSA used in this exploratory manner is prone to Type 1 error due to the large number of

significance tests (i.e., analysing 17 communication categories). Thus, again following Bakeman and Gottman [248] (p.118), the data were only examined in case of a significant likelihood-ratio Chi-Square statistic ($G2$), indicating a significant association between categories.

Table 8 Kendall's tau partial correlation analyses.

	Match Outcome	Mean Team Satisfaction	Mean Team Cohesion
Match Outcome	-		
Mean Team Satisfaction	0.57***	-	
Mean Team Cohesion	0.38**	0.58***	-

*Result of Kendall's tau partial correlation analysis with post hoc Bonferroni correction. There was a significant correlation between team cohesion and match outcome; between team cohesion and satisfaction; and between team satisfaction and match outcome. Asterisks represent Bonferroni-corrected p-values; ** p < .01; *** p < .001.*

5.6 Results

The average match duration was 28 minutes and 31 seconds (SD=79.08 seconds), which is the typical duration observed in League of Legends (see [131] for reference). Thirty-six teams won and twelve teams lost. A Chi-Square Goodness-of-Fit test was used to determine whether the observed match outcomes followed the expected distribution of match outcomes (an equal chance of winning and losing). The Chi-Square Goodness-of-Fit test indicated that the observed differences in match outcome were statistically significant, $\chi 2(1) = 12.0$, $p < .001$. Teams in our sample won more than expected, assuming a completely random (50/50) win-loss condition.

5.6.1 Is Team Cohesion Related to Performance and Satisfaction with the Team? (RQ1 and RQ2)

Team cohesion showed similar relationships with performance and satisfaction as found in other domains [10], [12], [19], [229]. Kendall's tau partial correlation analysis (Table 8) showed that, controlling for team satisfaction, there was a moderate correlation between team cohesion and match outcome, $\tau b = 0.38$, $p = .005$, 95% CI = [0.11, 0.6]. Controlling for match outcome, team cohesion was strongly correlated with team satisfaction ($\tau b = 0.58$, $p < .001$, 95% CI = [0.36, 0.74]). There was also a strong

correlation between team satisfaction and match outcome (τb = 0.55, p < .001, 95% CI = [0.34, 0.74]).

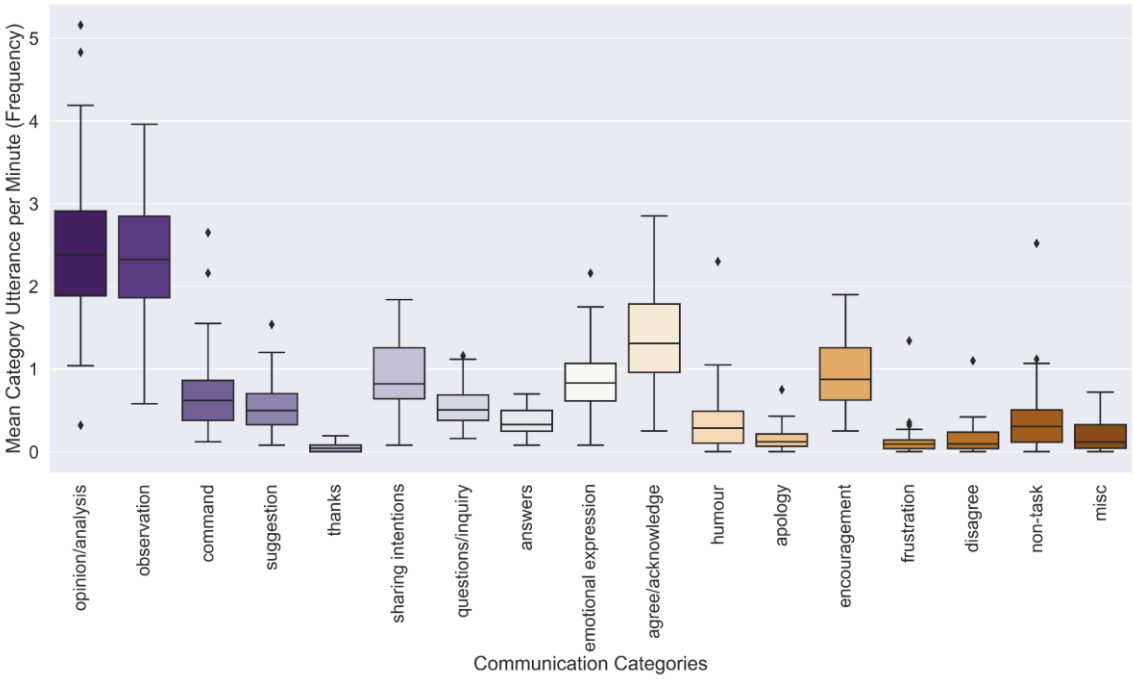

Figure 18 Distribution of category frequencies across the sample.

Distribution of category frequencies across the sample. Frequencies were calculated as mean category utterance per minute.

5.6.2 Is There a Relationship Between Communication Frequency and Team Cohesion? (RQ3)

Mean Words per Minute (Mean WPM) and Cohesion.

We investigated whether cohesion was linked to communication frequency (mean WPM), and whether communication frequency was linked to team performance (match outcome). Kendall's tau partial correlation analysis showed that there was a small correlation between mean words per minute and mean team cohesion that was significant, τb = 0.24, p = .047, 95% CI = [-0.04, 0.49]. In contrast to the communication-performance relationship previously observed in both co-located and virtual non-digital game teams [69], [70], [107] communication frequency (mean WPM) was not significantly correlated with performance (match outcome), p = .861.

Mean Category Utterance per Minute (Mean CPM) and Cohesion.

We then investigated whether cohesion was correlated to any specific communication category. The distributions of the categories indicate that Opinion/Analysis and Observation categories had the highest frequencies (Figure 18). Kendall's tau partial correlation analysis was conducted on the mean category frequency per minute (mean CPM) of each category and showed that no single communication category was correlated with team cohesion.

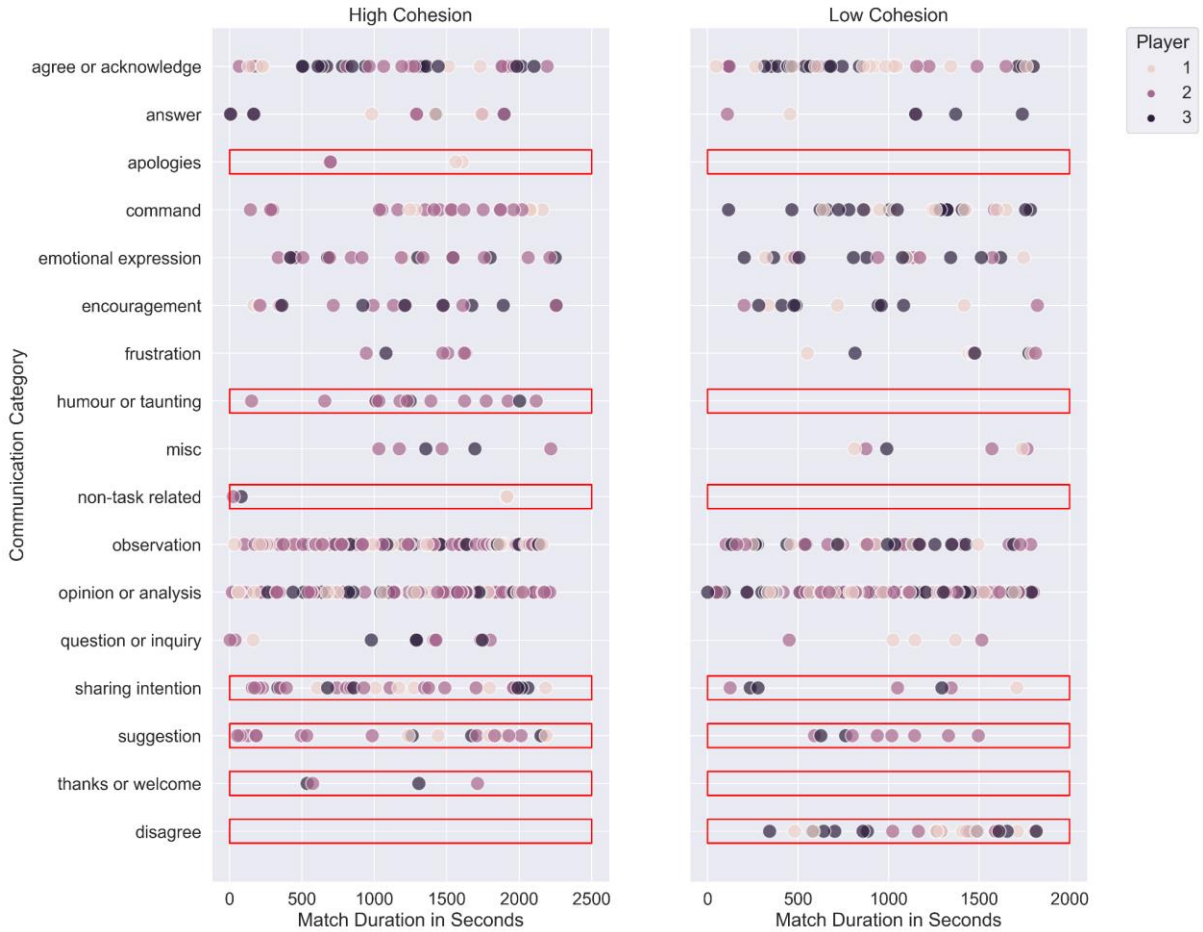

Figure 19 Communication categories across the match duration for two teams.

This graph shows communication across the match duration for the two separate case study teams: a high-cohesion team (left) and a low-cohesion Team (right). Each communication instance (represented by the data points) is categorised (y-axis). The colour of the data points reflects the players. In both teams, only three (out of five) players were study participants. The red boxes highlight the observable differences in communication between the teams.

5.6.3 Are There Potential Communication Sequences that Indicate Cohesion? A Case Study. (RQ4)

Findings from LSA

We addressed our exploratory research question about communication sequences for potentially predicting team cohesion through a case study on two separate teams: a high-cohesion team (cohesion: M=6.61, SD=0.25) and a low-cohesion team (M=2.67, SD=1.67). Both were three-person teams (only three out of the five players were study participants) that lost the match. These teams were selected because they represented the high and low cohesion extremes, whilst having the same match outcome. This allowed us to investigate which communication sequences might lend themselves to further exploration as predictors of and differentiators between different levels of cohesion while controlling for the influence of the match outcome.

The high-cohesion team had lower communication frequency than the low-cohesion team (High: mean WPM = 73.03; Low: mean WPM = 105.16). The standard deviation of mean WPM (High: SD=23.09; Low: SD=38.38) showed that communication instances in the high-cohesion team were more constant across the match duration compared to the low-cohesion team. Figure 4 shows the distribution of communication statements across the match duration. A visual inspection of the data showed that the high-cohesion team differed from the low-cohesion team on communication categories related to the social (non-task related) dynamics in the team. For example, the low-cohesion team had no instance of Apologies, Humour/Taunting, Non-Task Related, or Thanks statements, but had high instances of Disagree statements. The high-cohesion team also seemed to differ from the low-cohesion team in terms of their patterns of Suggestion and Sharing Intention statements: In the high-cohesion team, players shared their intentions constantly throughout the game, whereas the low-cohesion team had few and sparse instances of sharing intentions.

As described in Section 5.5.3, we first checked for significant interdependence between the categories. The likelihood-ratio Chi-Square was significant for both the

high-cohesion team ($G2(225) = 285.84$, $p = .004$) and the low-cohesion team ($G2(169) = 213.65$, $p = .011$), indicating a significant interdependence between the categories for both teams. Hence, we proceeded with the analysis. Sequences were considered statistically significant at the .05 level if the z score was larger than 1.96 absolute. The effect sizes of statistically significant sequences are visualised in Figure 20.

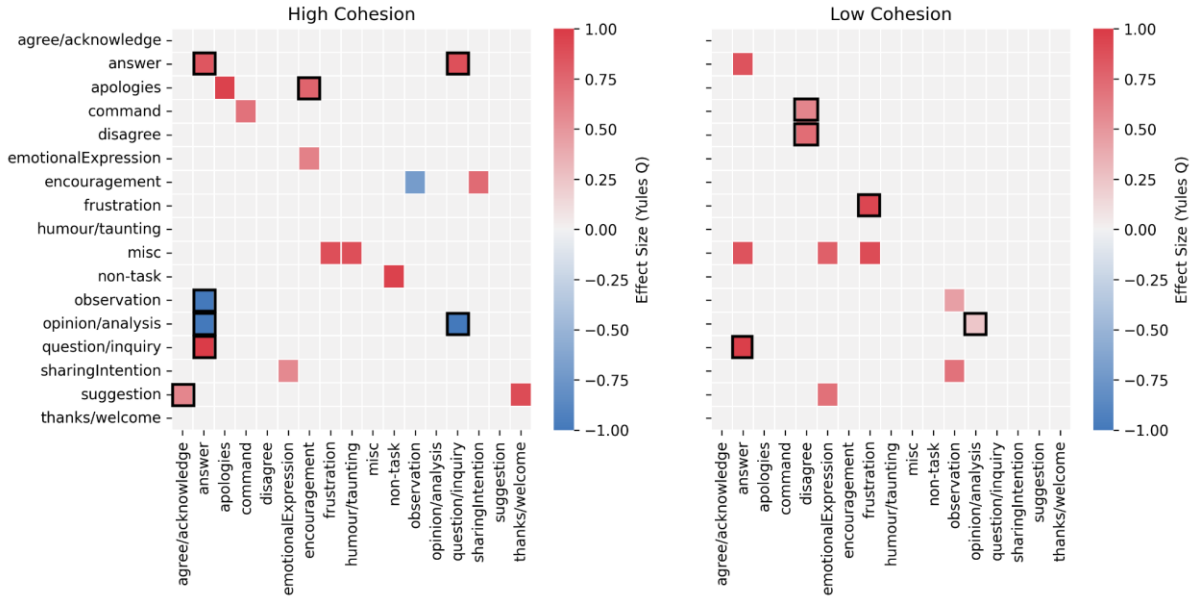

Figure 20 Results of sequence analysis on team communication.

This graph shows a comparison of all the significant sequences between the high-cohesion team (left) and low-cohesion team (right), with valid sequences after the filtering step described in Section 5.3.1 highlighted with a black border. Sequences are read from the vertical axis to the horizontal axis (e.g., in the high-cohesion team, questions (question/inquiry on vertical axis) are strongly followed by answers (on horizontal axis). Sequences that are more likely to occur are represented by red squares. Sequences that are less likely to occur are represented by blue squares. The luminance of the squares reflects the effect size of the sequence, represented by Yules Q.

Removing 'Invalid' Sequences from Further Analysis.

A focal point of the exploratory analysis is to identify meaningful exchanges between members that might influence team cohesion development. However, a limitation of the LSA is that it does not differentiate between speakers: this analysis does not indicate whether the sequence of statements is made by the same player or reflects an interaction between two players. In addition, the analysis does not differentiate between conversations because it was conducted on sequenced data without a time domain. This means that a sequence of statements may come from two different conversations or conversation periods.

For these reasons, we employed a filtering step before further analysis: the lead researcher cross-referenced the statistically significant sequences with the original video, identified the instances of the sequence in the transcript, and noted the number of instances of sequences that reflected exchanges between two players in the same conversation period. A sequence was subsequently only included in further analysis if 80% of instances met this condition. Sequences containing the 'Miscellaneous' category were also removed since the category was used to label ambiguous statements. Before this filtering process, there were 18 statistically significant sequences in the high-cohesion team and 12 in the low-cohesion team. After the filtering, there were 8 remaining sequences in the high-cohesion team and 5 remaining sequences in the low-cohesion team (see Figure 20 for comparison. Squares outlined in black are valid sequences). Only one was shared: in both teams, 'Questions' were extremely likely to be followed by 'Answers' (High: Z =14.86, $p < .001$, Q = 0.99; Low: Z = 7.35, $p < .001$, Q = 0.97).

Comparison of Sequences after Filtering.

In the following, we report the main differences in communication sequences between the high-cohesion and low-cohesion team. We provide examples of noteworthy sequences in Table 9 (labelled HCx for examples from the high-cohesion team, and LHx for examples from the low-cohesion team). In the high-cohesion team, an Apology was highly likely to be followed by Encouragement (Z =2.03, $p = .021$, Q = 0.77; see example HC1 in Table 9). There were no instances of apologies in the low-cohesion team, so there was also no occurrence of an Apology→Encouragement sequence. The high-cohesion team was also highly likely to agree on suggestions (Suggestion→Agreement/Acknowledgement, Z =2.81, $p = .003$, Q = 0.58; e.g., HC2 and HC3). Although the Suggestion→Agreement/Acknowledgement sequence occurred in the low-cohesion team, it was not statistically significant (Z = 1.02, $p = .154$).

Table 9 Transcript samples of different communication sequences.

Example ID	Player: Statement [Code]
HC1	P1: Yeah, yeah. I should have teleported. [*Apology*] P2: That's okay. [*Encouragement*]
HC2	P1: Fall to Drag[on] I think. [*Suggestion*] P2: Yep, fall to Dragon. [*Agree/Acknowledge*]
HC3	P2: On the bright side, if you want, you can [go] back and come back and get the Blue? [*Suggestion*] P3: I think I would like a blue, yes. [*Agree/Acknowledge*]
HC4	P2: What's happening? [*Question*] P1: I'm kind of just wandering around. [*Answer*] P2: I back off yeah? [*Question*] P1: Yeah. there's three of them over here so I think it might be warded [*Answer*]
HC5	P1: We just go Drag[on] I think. This is Soul [Dragon] right? [*Question*] P2: Yeah. [*Answer*] P3: No. [Answer]
HC6	P2: Who am I against again? [*Question*] P3: Probably against Renekton. [*Answer*] P2: Trundle [answering own question]. Nah, I'm Jungle. [*Answer]*
LC1	P1: I don't think I can do much right now because Nunu is just gonna keep ganking [the] bottom [lane]. [*Opinion/Analysis*] P2: Same here. We will have the tools just not right now. [*Opinion/Analysis*]
LC2	P2: It's going to be tough this one. [*Opinion/Analysis*] P1: I just think that was really bad because they're on Soul point now so we've put the game in their hands. [*Opinion/Analysis]*
LC3	P1: No, we can't let them do Drake. That's Soul Drake. [*Opinion/Analysis*] P3: Yeah, but let them [get] Drake because we cannot really fight. [*Opinion/Analysis*]
LC4	P1: Ignore him [referring to opponent]. You just need to push in [the] Mid [lane]. [*Command*] P3: No, no, no, look there's a fight. [*Disagree]*
LC5	P3: That doesn't really make sense [in response to a teammate's opinion]. [*Disagree*] P1: What? So running at Garen [in the] top lane makes sense when we need agency over the mid lane? [*Disagree].*
LC6	P1: Yeah, exactly. that's my point dude. I need you to come with me and help me ward. Do you just ignore me? [*Frustration*] P2: Yeah, but if they don't go to Baron immediately, they won't go to Baron [for] a few minutes. [*Frustration*] P1: No, I didn't want Baron, I wanted to [put a] ward [at the] Dragon. I was going down here but nobody came with me. You guys all went here [instead]. [*Frustration*] P3: Yeah, because they [had] warded this jungle already. They took control of the jungle. [*Frustration*]

Examples of significant and valid communication sequences, labelled with an ID that also indicates which team they were taken from (high-cohesion as HC; low-cohesion as LC).

While the Question→Answer sequence was significant in both teams, the additional presence of a significant Answer→Question sequence (Z =4.54, $p < .001$, Q = 0.88) in the high-cohesion team seems to suggest that this team engaged in more elaborate question and answer sequences. An inspection of the transcript shows that the Answer→Question sequence tends to appear in conjunction with a Question→Answer sequence (HC4). The high-cohesion team also had a significant Answer→Answer sequence (Z =4.32, $p < .001$, Q = 0.85). In the transcript this sequence occurs when all players of the high-cohesion team give an answer to a question (HC5) or when a player answers their own question (HC6). These additional sequences did not occur in the low-cohesion team. There were also statistically significant unlikely sequences in the high-cohesion team. For instance, Observation

statements were less likely to be followed by Answer statements (Z = -2.1, *p* = .018, Q = -1.00), as should be expected given that Answer statements were defined as statements in response to questions. In addition, Opinion/Analysis statements were unlikely to be followed by a Question (Z = -2.1, *p* = .022, Q = -1.00) or an Answer (Z = -2.1, *p* = .018, Q = -1.00) in the high-cohesion team. There were no statistically significant unlikely sequences in the low-cohesion team.

The low-cohesion team had a significant Opinion/Analysis→Opinion/Analysis sequence (Z = 2.12, *p* = .017, Q = 0.24) suggesting that the team engaged in discussions around their opinion or analysis of the situations in the game. This sequence was not significant in the high-cohesion team (significant if Z score is above 1.96 absolute; Z = 1.86, *p* = .031). An inspection of the transcript shows that these sequences can reflect different kinds of discussions. Some reflect discussions around the analysis of a situation or the game state, which helps the team to plan their actions (e.g., LC1). Others reflect discussion on the analysis of past actions or fights and the impact of their outcome (e.g., LC2). The Opinion/Analysis→Opinion/Analysis sequence also reflected conflicting opinions on the appropriate plan of action for a given game state. In example LC3, the team had conflicting opinions on whether they could defend an advantageous team objective (i.e., the Drake) from being claimed by the enemy team.

Without inspecting the transcript, it would be difficult to gain the contextual information required to situate the interactions between the team members. The low-cohesion team was also likely to reject commands, indicated by a significant Command→Disagree sequence (Z = 2.99, *p* = .001, Q = 0.5; LC4), and disagree with each other, indicated by a significant Disagree→Disagree sequence (Z = 4.73, *p* < .001, Q = 0.72; LC5). There was also a significant Frustration→Frustration sequence (Z = 6.45, *p* < .001, Q = 0.93; LC6). Since the Frustration category does not contain a referent, we had to identify who the frustration was being directed to (either self, teammate, or opponent). An inspection of the transcript showed that the Frustration→Frustration sequences reflect obvious frustration between members of the same team.

5.7 Discussion

Our analysis showed that team cohesion had a moderate positive correlation with performance (match outcome) and a strong positive correlation with satisfaction in *League of Legends* STATs. Communication frequency (mean words per minute) had a significant small correlation with team cohesion. There was no significant correlation between the frequency of any single communication category (mean category utterance per minute) and team cohesion. We conducted further exploratory qualitative analyses on the communication categories using LSA on a subset of our sample: a high-cohesion team and a low-cohesion team (who both lost the match). This allowed us to identify potential communication sequences that may be used as proxy indicators of cohesion in the future, while controlling for the effect of match outcome. We found only one shared sequence: Question→Answer. The remaining valid and significant sequences of the high-cohesion team were: Apology→Encouragement, Suggestion→Agree/Acknowledge, Answer→Answer, and Answer→Question. On the other hand, the remaining sequences of the low-cohesion team were: Opinion/Analysis→Opinion/Analysis, Disagree→Disagree, Command→Disagree, and Frustration→Frustration. We discuss these findings in the following sections.

5.7.1 The Cohesion-Performance and Cohesion-Satisfaction Relationships in digital games (RQ1 and 2)

In line with the non-games literature, we find significant relationships between team cohesion, performance, and satisfaction. To our knowledge, no other digital games studies have conceptualised or defined cohesion in line with the wider cohesion literature. Studies that have mentioned the importance of cohesion in digital games, have mixed its conceptualisation with other concepts [168], [169], have used definitions and conceptualisations that do not reflect the current state of the literature [167], or have mentioned team cohesion without providing a definition [166]. This makes it difficult to compare or generalise findings from digital games to non-game teams. By defining and conceptualising cohesion in line with the wider cohesion

literature, our findings not only add to the argument that cohesion is important to teamwork in competitive team-based digital games [167], [263], but expand the body of knowledge in the wider cohesion literature by adding a new domain of inquiry: digital games.

Importantly, cohesion was more strongly related to satisfaction than to match outcome. Although satisfaction is arguably also influenced by the match outcome, these relationships suggest that we can create more satisfying experiences when playing with strangers in competitive games by facilitating the development of cohesion in ad hoc teams. Identifying and encouraging cohesion-building behaviours may be a potential solution to reducing the notoriously common negative experience of playing with strangers in competitive team games like League of Legends [166], [177], [245]. However, given that our sample had relatively few losing teams compared to winning teams, we acknowledge that these findings may be confounded by the match outcome. A larger sample of losing teams is required to comprehensively investigate whether the cohesion-satisfaction relationship is moderated by the match outcome. If this relationship can be observed in a larger sample of losing teams, it implies that greater attention should be paid to understanding how to develop cohesive ad hoc teams in competitive digital games.

Combined with evidence that teamwork skills acquired through games are transferable to non-game situations [59], [264], our findings also suggest that games can be used as a test bed to investigate constructs such as cohesion that have been identified as important for effective teams. Additionally, our findings lend support to the argument that team-based digital games are a viable environment to address existing and emerging issues of team performance research [58], [131]. Indeed, similar arguments have been made by Toups et al. [59] and Cooke et al. [264] who showed that digital games can improve communication and coordination skills in real-world firefighting and military scenarios. Our study adds to the growing body of research supporting the use of digital game STATs to investigate behaviours and success factors of real-world STATs [58], [131].

5.7.2 The Relationship Between Team Cohesion, and Communication Frequencies and Categories (RQ3)

Communication may be a potential proxy measure of cohesion because of its instrumental and social functions [236], which can influence the development of task and social bonds that give rise to cohesion [11], [224]. We found a small, significant positive correlation between communication frequency and cohesion, in line with the meta-analysis on communication in non-game teams [69]. We also investigated the relationship between communication frequency and performance as there are multiple meta-analyses supporting this relationship in non-game teams [69], [107]. However, we did not find a significant relationship between the two variables. We proceeded to investigate whether specific communication categories were correlated with team cohesion and did not find any significant relationships.

Our findings echo sentiments of the STATs literature that frequency counts alone are unreliable measures of performance—regardless of whether they are raw frequencies of words or frequencies of communication categories [72], [121]. Instead, communication frequency may have a stronger influence on affective perceptions like team cohesion. It is possible that high communication frequency indicates that members are willing to engage in working towards the team goal. This in turn would give rise to cohesion since members show a shared attraction to the task, as per the definition of cohesion [11]–[13]. However, analysing frequency alone lacks the context needed to fully understand how cohesion emerges through communication.

While we speculate that communication influences cohesion, given the cyclical nature of team processes [56], it is also possible that cohesion influences communication frequency. Team members who perceive cohesion may feel more inclined to participate in communication than those that do not. The nature of this study limits our ability to tease apart this relationship – understanding the boundary conditions of this relationship would enable us to more clearly identify casuality in the future. Nonetheless, our findings suggest that communication frequency may be a useful proxy indicator of cohesion that can be measured before the outcome is known.

5.7.3 Communication Sequences in a High vs. Low-Cohesion Team (RQ4)

Our exploratory analysis compared the communication sequences between a high- and low-cohesion team (while controlling for the match outcome). We found that the high-cohesion team was characterised by interactions with relatively positive valence, and the low-cohesion team by interactions with relatively negative valence. The teams did not seem to differ on strictly task-related interactions.

The sequences in the low-cohesion team suggest that the team was not unified in their understanding of the changing environment or in their plans for action, as indicated by the Command→Disagree sequence and our inspection of the Opinion/Analysis→Opinion/Analysis sequence occurrences in the transcript. If the team had a shared understanding of the changing environment, they would likely reach consensus on solutions and plans of actions with little need for discussion. However, the sequences reflected conflict between a player's understanding of the situation (and corresponding plan of action) and the rest of their team. This in turn led frustrations to rise as players on the team were unable to manage their conflicting views, as indicated by the Frustration→Frustration sequence.

Sequences in the high-cohesion team suggested the opposite: the *absence* of the sequences observed in the low-cohesion team, combined with the presence of the Suggestion→Agree sequence suggests that members on the high-cohesion team were generally unified in their assessment of the environment and plan of action. Additionally, members of the high-cohesion team apologised for their mistakes, and members responded to apologies positively—by encouraging the person who had apologised (Apologies→Encouragement). In contrast, there were no apologies in the low-cohesion team even when mistakes were made. These findings suggest that cohesive teams are generally unified in their approach to the task, acknowledge when mistakes are made through apologising, and do not punish but instead encourage each other when a team member admits their mistake. Referring back to the definition of team cohesion (as the shared bond or attraction that drives team members to want to work together and stay together [11]–[13], when these sequences occur, it may

contribute to cohesion because a unified, encouraging, and forgiving team climate makes working together more attractive. Importantly, it shows that members remained committed to achieving the team objective, despite mistakes. This in turn led to a sense of cohesion even though the team lost. Reflecting on their experience with the strangers on their team, a player from the high-cohesion team in the case study stated:

> "It was pretty much just like any other game between friends. We're trying to win without worrying too much if things go wrong." [P1; high-cohesion team; match outcome: loss]

Importantly, this study shows that it is possible to have a sense of cohesion in spite of a negative team outcome (i.e., losing the match) while playing with strangers. Further, cohesion is important not just to performance but also because players of cohesive teams feel satisfied (indicated by the strong positive cohesion-satisfaction correlation). It also provides evidence that communication can be used as a proxy indicator of cohesion, but that the interaction between members in the form of communication sequences is potentially more insightful than communication frequencies. Investigating communication sequences more comprehensively informs how communication influences cohesion.

5.8 Limitations and Future Work

We acknowledge that our findings may be affected by the fact that survey measures were administered at the end of the match: participants may have been biased by the match outcome. Similar to Hudson and Cairns' [263] findings, it is unclear whether perceptions of cohesion gave rise to higher levels of performance, or whether participants presumed that their team was cohesive since they won the match. This is one of the main reasons the literature has called for investigation of unobtrusive behavioural measures of cohesion—to untangle the relationship between cohesion and performance [37], [40]. Therefore, we supplemented the cohesion survey with unobtrusive, longitudinal (i.e., measured across the match duration), behavioural

data—team communication—that can be measured before the team outcome is known. Although we are not certain if this method fully overcomes the confounds, it is a more objective measure of cohesion than survey measures.

An interesting outcome that imposed limitations on our analysis is that teams in the study won more than expected (36 of 48). This could implicate our game mode or the voice communication as confounds. However, the chosen game mode "Ranked Flex" is typically used by players who know each other, i.e., teams with a history of working together. As such, we can reasonably assume that they would also be in voice communication together. Moreover, League of Legends' matchmaking system ensures that teams of similar skill level are matched together, which generally should ensure equal chances of winning [265]. For these reasons, a large skill difference between the teams or advantages from being on voice communication seemed unlikely. This unexpected outcome may warrant further investigation.

As a result of the unexpected distribution of wins and losses, we were unable to conduct an aggregate investigation on communication sequences and cohesion, while controlling for the influence of the match outcome. Thus, the sequence analysis findings are derived from a case study of two teams. Further investigation is required to determine if the sequences can be observed in larger samples and generalised to other competitive team games. There now exists win prediction algorithms that can dynamically map in-game behaviours and events to a team's probability of winning [266]–[268]. If valid, generalisable communication sequences can be identified, an avenue for future investigation is to combine advanced win prediction algorithms with communication analysis to investigate whether cohesion can be predicted by a team's communication valence or sequences, independent of the match outcome. Doing so would provide additional empirical evidence for communication as a proxy indicator of cohesion.

Finally, it is possible that participants' communication behaviour might be influenced by their knowledge of the purpose of the study. However, we have reason to believe that this is unlikely. Firstly, the presence of low cohesion teams suggests

that players likely treated the match no differently to a non-experiment match. If participants were actively aware of the purpose of the study they should behave in socially desirable ways (i.e., try to put on a collaborative front). Instead, this sample contained teams that were obviously in conflict based on their communication data. Secondly, we took every precaution to create a gaming environment that most closely matched participants' typical environment. For instance, participants were instructed to play in full screen and were informed that the researcher was not going to be present during the match – this was done to increase the likelihood that participants felt comfortable and would play as they normally do. While we believe that these factors make it unlikely that participant behaviour was influenced by the study purpose, future work could consider taking a baseline sample of participants communication behaviour for better comparison of deviation.

5.9 Conclusion

In this paper, we reported on a mixed-methods study investigating team communication as a proxy indicator of cohesion. We show that team cohesion influences performance and satisfaction in *League of Legends*, and that communication word frequencies can be used as a proxy behavioural indicator of cohesion. Through an additional case study of communication sequences in a high-cohesion and low-cohesion team we identified sequences that can potentially predict team cohesion and warrant future investigation. This study supports the notion that team-based digital games are viable test beds to investigate and address issues in team performance research.

Chapter 6: General Discussion

6.1 Summary of key findings

In this chapter, I summarise the findings across the three empirical chapters, consider the theoretical and practical implications from my thesis, and suggest areas of future research on identifying behavioural indicators of team cohesion in swift starting action teams (STATs). The objective of this thesis was to use digital games to identify potential behavioural indicators of team cohesion. This work was motivated by gaps in the literature on cohesion predictors. Despite strong empirical evidence for the positive influence of cohesion on various team outcomes like performance, satisfaction, and retention, much less is known of how to cultivate cohesion [37], [39]. This is driven by the reliance on static, often subjective measures (i.e., self-report) and static study designs (i.e., cross-sectional studies) which conflict with the nature of cohesion as a dynamic construct with temporal properties. As such, the cohesion literature is at a turning point: researchers are now attempting to develop unobtrusive behavioural measures to capture the temporal aspects of cohesion [29], [40], [42]. Doing this would enable cohesion to be continuously monitored, which would enable predictors to be identified in a precise manner. Moreover, unobtrusive behavioural measures are particularly important for investigating cohesion in swift starting action teams (e.g., emergency medical teams, military units, crisis management crews) – teams that operate in high-risk environments under evident time pressure and with dire consequences for poor teamwork – as current methods for assessing cohesion are impractical and sometimes impossible to apply to such teams. Nonetheless, as noted by Salas et al. [224], these unobtrusive behavioural measures must be supplemented with current validated measures (i.e., cohesion surveys) to ensure that these measures actually capture cohesion.

This thesis was situated within the context of STATs in *digital games* because they parallel the environmental demands and team structure of real-world STATs and

afford greater accessibility to such teams. Driven by the call to develop unobtrusive behavioural measures of cohesion, the key research questions of this thesis are:

1. RQ1: What factors influence cohesion in STATs in digital games?
2. RQ2: What methods are suitable for studying STATs in digital games?
    a. Can team communication be used as a proxy indicator of cohesion?
    b. If so, what communication metrics best indicate team cohesion?
3. RQ3: Is cohesion linked to outcomes such as performance and satisfaction in STATs in digital games, as has been shown in real-world STATs?

6.1.1 RQ1: What factors influence cohesion in STATs in digital games?

In addressing RQ1, it was evident that there was a lack of studies directly investigating team cohesion in STATs in digital games. Hence, we conducted an interview study on players' experiences in STATs to obtain initial factors that might relate to cohesion (*Chapter 3*). The interview focused on factors that influenced players intention to return to play with a teammate after the first encounter. Intention to return (or remain) to the team is a by-product of cohesion [3], [269]. For this study, intention to return to play with a teammate was operationalised as adding the teammate to their Friend List or inviting a teammate for a consecutive match after the first encounter. Transcripts of the interviews were thematically analysed, identifying four main themes: (1) unexpected bonds with strangers, (2) evaluation based on task-related factors, (3) evaluation based on social-emotional factors, and (4) the moderating effect of communication medium. The evaluations that players make of strangers map onto the task and social dimensions of cohesion. In addition, the extent that these factors influence intention to return to play with a teammate seemed to be moderated by the communication medium (i.e., voice chat vs text chat). The strength of influence between the factors and intention to return to player could not be determined using this method. Nonetheless, the findings from *Chapter 3* are in line with the theoretical conceptualisation of cohesion as an affective state that emerges and develops through the interactions between team members [30], [74].

The findings from the first empirical chapter (*Chapter 3)* indicated three things. First, the findings provided insight into *where* to look for potential factors related to

cohesion: *team communication*. The factors identified via thematic analysis primarily manifest through the way a player communicates (except the factor of exhibiting skill and competence in their role). This insight focused subsequent empirical studies in the thesis on investigating team communication as a proxy behavioural indicator of cohesion. Second, within team communication, the findings provided insight into *what* metrics to consider. Based on the findings, communication metrics that may influence cohesion are (1) the *volume* of communication (i.e., the extent that teammates are engaging in team communication), (2) *the content* of communication (i.e., what teammates are saying), and (3) *the exchange or sequence* of communication between teammates (e.g., a teammates' response to constructive criticism). Finally, the findings provided some insight into *how* the communication medium (i.e., voice chat vs text chat) constricts or enables the communication metrics outlined above.

6.1.2 RQ2: Can team communication be used as a proxy indicator of cohesion?

Based on the findings from *Chapter* 3, the remainder of the thesis was focused on investigating team communication as a proxy indicator of cohesion. The empirical study in *Chapter 4* investigated *text communication* in ad hoc two-person teams using interaction process analysis based on Bales' coding scheme [114] while the empirical study in *Chapter 5* investigated *voice communication* in ad hoc three- and five-person teams using interaction process analysis based on an adapted coding scheme from Zijlstra *et al*.'s [216] study on aviation crews.

Chapter 4 revealed that in two-person ad hoc teams communicating via text, communication is more task-oriented than socio-emotional. This suggests that even in playful environments like digital games, interactions are predominantly task-oriented when teams are ad hoc and operate in time-limited environments, in line with previous research on swift starting action teams [52]. The findings from *Chapter 4* indicate a negative correlation between volume of text communication and team performance. If this relationship is causal, it suggests that a high volume of text communication is detrimental to team performance (operationalised as the number of levels completed during the 45-minute play session) in this context. Based on the

content of communication (i.e., 25% suggestions/directions (code 4), 12% sharing observations and experiences (code 6), and 11% giving opinions (code 5), players seemed to use text communication primarily for collective decision making and problem solving. As coordinating team actions via typing is far more time-consuming than using pings or voice communication [215], it is not surprising that the volume of text communication is negatively correlated with performance. However, although cohesion was not measured in *Chapter* 4, it is plausible that the volume of text communication is *positively* related to cohesion. Since meta-analytic findings show a positive relationship between communication frequency and cohesion [69], [70], we speculate that when players participate in the decision-making and problem-solving process via team communication, it signals that they are committed and unified in achieving the team's goals. Combined with the positive sentiment in the team (showing friendliness was the second most frequent communication category), it is reasonable to speculate that team members felt cohesive in this study. Therefore, in the next empirical study (*Chapter 5*), cohesion was measured, and the communication-cohesion relationship was investigated. Nonetheless, the findings from *Chapter 4* suggests that communication (when operationalised as frequency) may be a proxy indicator of cohesion.

In the study in *Chapter 5*, a coding scheme developed to investigate communication in swift starting (aviation) teams was adapted to the context of STATs in *League of Legends*. Additional codes were iteratively added and refined to capture the nuance of communication in this context. In addition, cohesion and satisfaction were measured. The findings from this chapter indicated a positive correlation between communication frequency and cohesion, as expected. In addition, no specific communication categories had significant correlations with cohesion. These observations are supported by findings from previous communication-cohesion meta-analyses showing that cohesion is more strongly influenced by the frequency rather than quality (or content) of communication[69], [70].

This is also in line with the theoretical assumption of cohesion as an emergent state that arises through the interactions between team members [74]. If cohesion

relies on interaction instances to emerge and develop, it seems likely that when team members actively engage in communication, they gain more information about team members that help form perceptions of cohesion. Together, it suggests that *communication frequency* can be used as a proxy indicator of cohesion and may be a better indicator of cohesion than communication content/categories.

We also investigated the *exchange* of information between team members as research from the aviation and healthcare domain indicates that we may be missing insights by only looking at aggregate statistics [71], [72], [111], [121]. Analysing the exchange of information between players provides a more comprehensive understanding of how the dynamic of a team is shaped by the communication between members. Therefore, in *Chapter 5*, we conducted a case study on the communication sequences in two losing teams with different self-reported levels of cohesion. From the case study, two key observations can be derived. First, in the high cohesion team, players owned up to their mistakes. Instead of being punished or blamed, their apologies were met with encouragement (evidenced by significant Apology → Encouragement sequence). This interaction likely contributed to cohesion through signalling some sort of similarity between the players in terms of their approach to teamwork (e.g., both players understand that mistakes are inevitable and the way to overcome a setback is through encouragement and motivation). Interestingly, these findings supported the findings from *Chapter 3* where players stated that they tended to add strangers (to their Friend List or invite them back for a subsequent match) who provided encouraging and positive communication in the face of adversity.

A second observation was the potential role of having a shared mental model in driving or facilitating cohesion. A shared mental model is the common understanding that individuals in a team have regarding the requirements of the task and how their work will be coordinated [246], [270]. Shared mental models have been positively associated with overall team performance in previous research because it allows teams to make unified predictions of changes in the environment and quickly develop an appropriate course of action [246], [271], [272]. Developing a shared mental

model possibly contributes to cohesion through behaviours that signal that a team is unified in their approach to achieving team objectives. For instance, in the high cohesion team, Suggestion → Agree/Acknowledge was a significant sequence which indicates that team members are 'on the same page' about plans of action. In contrast, the sequences Opinion → Opinion, Command → Disagree, and Disagree → Disagree indicates that team members had differing views of the state of the environment and appropriate courses of action. Given that teams operated in a time-pressured environment, disagreements around plan of actions were detrimental to performance, which in turn could signal that there was a lack of shared commitment or unity towards achieving the team objectives. As a result, members perceived low cohesion. Importantly, these observations could not be derived from aggregate statistics alone. Therefore, the *communication sequences* (or *exchange* of information between team members) is likely a proxy indicator of cohesion.

6.1.3 RQ3: Is cohesion linked to outcomes such as performance and satisfaction in digital games, as in real-world STATs

Since the research decisions, design, and methodology was based on and inspired by the non-digital game literature on teams, it was important to establish the relationship of cohesion with well-known team outcomes such as performance and satisfaction. By doing so, we can build a case for digital games as a lens to study real-world swift starting action teams. This will enable findings from digital games STATs to be generalised to the real-world. Findings from *Chapter 5* provided support for the cohesion-performance and cohesion-satisfaction relationship, although the cohesion-satisfaction relationship had stronger effects. This is expected given that cohesion and satisfaction are affective factors. Furthermore, these findings support Hudson and Cairns' [168] findings that cohesion is positively correlated with performance in digital games. Like them, however, we acknowledge that we were unable to tease apart the cohesion-performance relationship since cohesion was measured *after* the match. Nonetheless, the findings suggests that research outcomes from investigating cohesion in STATs in digital games may be applicable to real-world STATs.

6.2 Future directions

This thesis addressed a range of research questions pertaining to developing an unobtrusive behavioural indicator of team cohesion for swift starting action teams using digital games. Taking a mixed-method approach, the findings from this thesis highlight the complexity of developing such measures. One of the main challenges is to initially validate that the behavioural indicators reflect cohesion by correlating them with validated self-reported measures of cohesion [37]. However, given that STATs cannot be stopped mid-task, the self-reported measure of cohesion will always be taken *after* the team's outcome is known, which influences self-reported cohesion.

6.2.1 Developing a standardized coding scheme to investigate communication in STATs

Chapter 4 highlighted the need to use a more context-relevant coding scheme. The Bales IPA coding scheme is a general and broad coding scheme, having been used in a variety of contexts. Although the coding scheme was expanded to include two new categories ('task-irrelevant content' and 'corrections'; similar to Pena and Hancock's [115] study), the coders suggested that more categories were needed to capture the nuance of communication in the digital game context and/or that categories needed to be refined. Therefore, in the next study *(Chapter 5*), a coding framework that was created specifically for investigating swift starting (aviation) teams [52] was adapted to the context of STATs in *League of Legends* [68]. Codes were iteratively refined and added to the coding scheme. By adapting an existing coding framework created for real-world STATs, we developed a coding framework that was more suitable to investigate communication in STATs in digital games.

Future work should validate this coding scheme in STATs operating in different game genres. We hypothesise that the categories chosen are broadly applicable to most team-based games where ad hoc teams operate in time-limited environments. However, the communication patterns might change depending on the genre. To illustrate, First Person Shooter (FPS) games have a first-person point of view while

Multiplayer Online Battle Arena (MOBA) games that have an isometric top-down point of view. This point of view influences the amount of information players can see at any one point. We hypothesise that acknowledgements to commands would be much more prevalent in FPS games and have a larger influence on match outcome, compared to MOBA games since FPS games have a more restricted view. Given that FPS games are also more fast paced than MOBA games, they likely require tighter coordination between team members. As such, there may additional communication categories that teams use to coordinate their behaviour. Additional validation of the coding scheme would tell us whether communication in digital game STATs is relatively standardised or whether additional categories occur in different game environments.

6.2.2 Improving methods for obtaining and analysing team communication data

One of the main challenges was obtaining high quality transcripts of communication from speech *(Chapter 5)*. This became a laborious effort as open source (i.e., VOSK) and commercial speech-to-text services (i.e., Otter.ai, Google, rev.com) performed poorly. This may be due to the domain specificity, the pace of communication in digital games, and the influence of accented English. Future work could look to develop high quality speech recognition for digital game communication as this would accelerate research on team dynamics in this domain.

In terms of analysis, *Chapter 5* indicated that communication sequence analysis was a particularly promising avenue to capture the exchange of information between members. This method allows researchers to capture how team member interactions influence the emergence and development of cohesion. In future, researchers could segment the team interaction around instances with performance feedback to investigate the impact of the interaction between team members on the outcome and subsequently, the impact of the outcome on future interactions. This will lend empirical insight into the theoretical model of team cohesion.

While insightful, one of the challenges faced when using sequence analysis in *Chapter 5* was verifying whether significant sequences accurately reflected the interaction between two members (in other words, avoiding false positives). To address this issue, transcripts and gameplay videos were manually checked. However, this process was time-consuming and posed a real challenge to investigating communication in teams with 3 or more members. Unfortunately, previous research using sequence analysis has primarily investigated communication in two-person teams [52], [73], [121] or have used a manual approach like us when investigating communication in larger teams [112], [118], [120]. Therefore, to investigate team member interactions at scale, future investigations should be directed towards developing algorithms that can identify valid interaction segments in teams larger than 3 members. We hypothesise that an algorithm that has accurate speaker diarization capabilities, rich syntactic knowledge, and environmental awareness will be able to identify valid interaction segments in such teams. Such software would not only speed up the analytics process but enable investigations on team interaction patterns to be conducted at scale.

6.2.3 Applying communication insights

The findings from this thesis suggest that there are communication patterns that differentiate high and low cohesion STATs. Specifically, that cohesion may be deduced from the volume of communication in a team, communication exchanges that contain affective information (e.g., apologising for mistakes and encouraging others), and communication exchanges that reflect the level of mental model similarity (e.g., whether there is consensus around course of action).

While further investigation is required to identify specific exchanges (sequences) that build or hinder cohesion, it seems plausible that these communication patterns may tell us about the trajectory of a team's level of cohesion. This trajectory may give insight into the emergence and development of cohesion over time. Using this insight, critical moments can be identified, and interventions can be developed to prevent a team from reaching the point where it disbands due to poor team functioning.

This has several applications. We may be able to develop steps to systematically cultivate cohesion in (1) STATs in games, to help strangers work better together and create more positive player experiences, (2) in esports teams, to develop higher levels of cohesion to facilitate long-term high performance, and (3) more importantly, with real-world STATs (i.e., emergency medical teams, military units, crisis management teams) where lives depend on the effectiveness of such teams. Communication analytics, and in particular, communication *sequence* analysis, has exciting prospects for advancing our understanding of building teams that are not only high-performing but also sustainable.

6.3 Final conclusions

In conclusion, this thesis has provided early empirical evidence for using communication metrics as proxy indicators of cohesion. The thesis also showed that digital games are a promising avenue for addressing existing and emerging issues in real-world team dynamics research. While current methods for acquiring high quality voice communication transcriptions and valid interaction segments in digital games are laborious, the speed at which developments within the automatic speech recognition (ASR) domain is moving (e.g., Open AI recently released their multilingual ASR model Whisper [273], [274]), combined with game developers' approaches to this issue (e.g., Riot Games has begun training their own ASR model in *Valorant* [183] for toxicity detection [275]) gives us confidence that these methods will soon be automated and potentially revolutionise how team dynamics research is conducted across domains. In short, this thesis has uncovered previously unidentified predictors of cohesion through investigating swift starting action teams in digital games.

Appendix

7.1 Team Cohesion Measure [98]

For each statement, please provide a response along a 7-item Likert scale.

1- strongly disagree, 2- strongly agree

Task

Our team was unified in its task focus.

Our team had a shared sense of task importance.

Our team was committed to our team's task.

Social

Our team members cared about each other.

Our team members had good relationships with each other.

Our team members enjoyed each other's company.

7.2 Additional analyses on communication sequences

7.2.1 Losing Teams vs Winning Teams

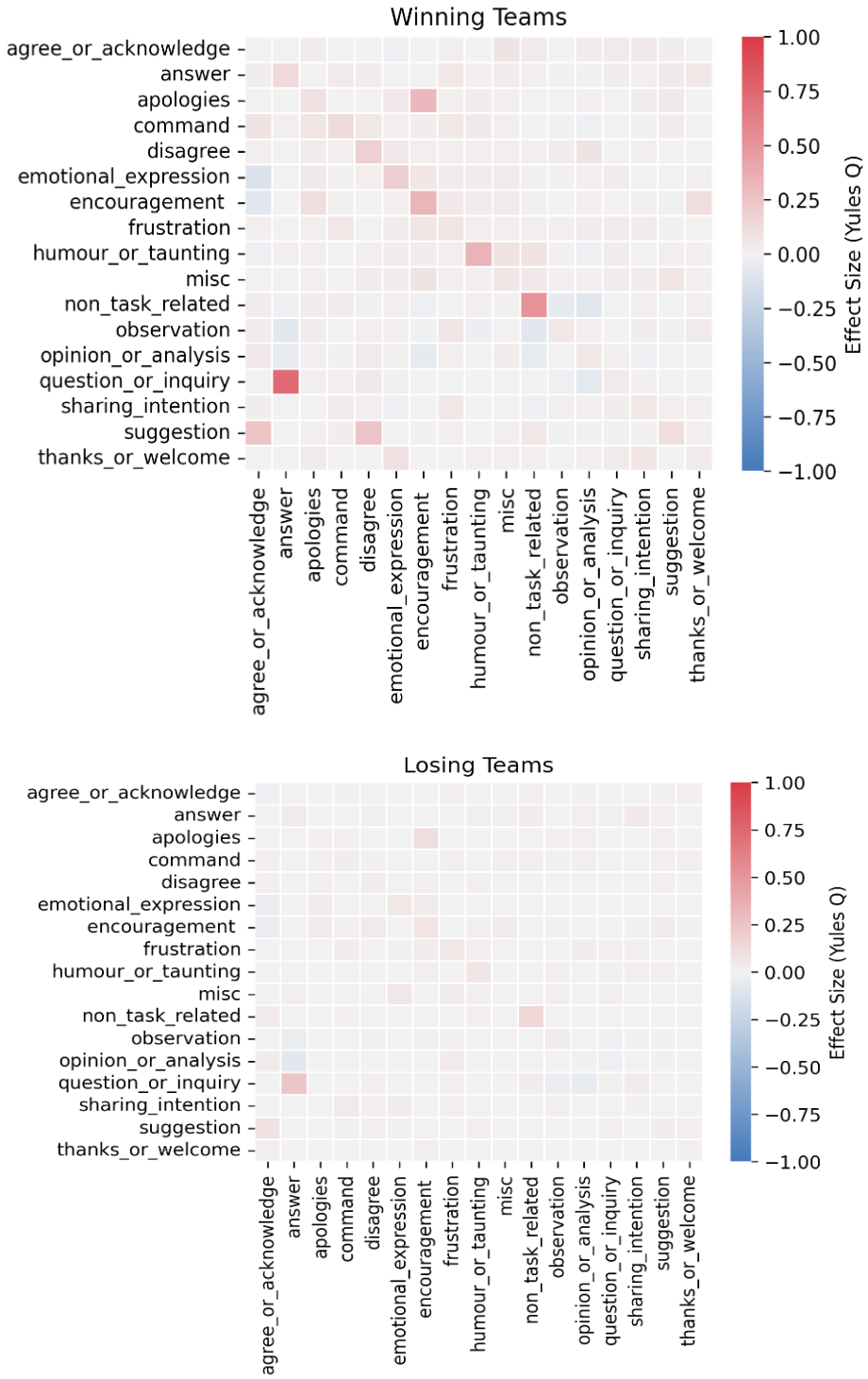

Figure 21 Comparison of sequences between winning and losing teams.

This graph shows a comparison of sequences between the winning teams (top) and losing teams (bottom). Sequences are read from the vertical axis to the horizontal axis (e.g., in the winning teams heatmap, questions (question/inquiry on vertical axis) are strongly followed by answers (on horizontal axis). Sequences that are more

likely to occur are represented by red squares. Sequences that are less likely to occur are represented by blue squares. The luminance of the squares reflects the effect size of the sequence, represented by Yules Q.

We conducted additional analyses to investigate whether sequences were different between winning and losing teams, on average. We split the sample into winning (n = 36) and losing teams (n = 12). Then we ran the sequence analysis on each individual sample and combined the samples to get a group average. Figure 21 shows the results from the analysis.

7.2.2 Middle Tertile Cohesion vs Upper Tertile Cohesion

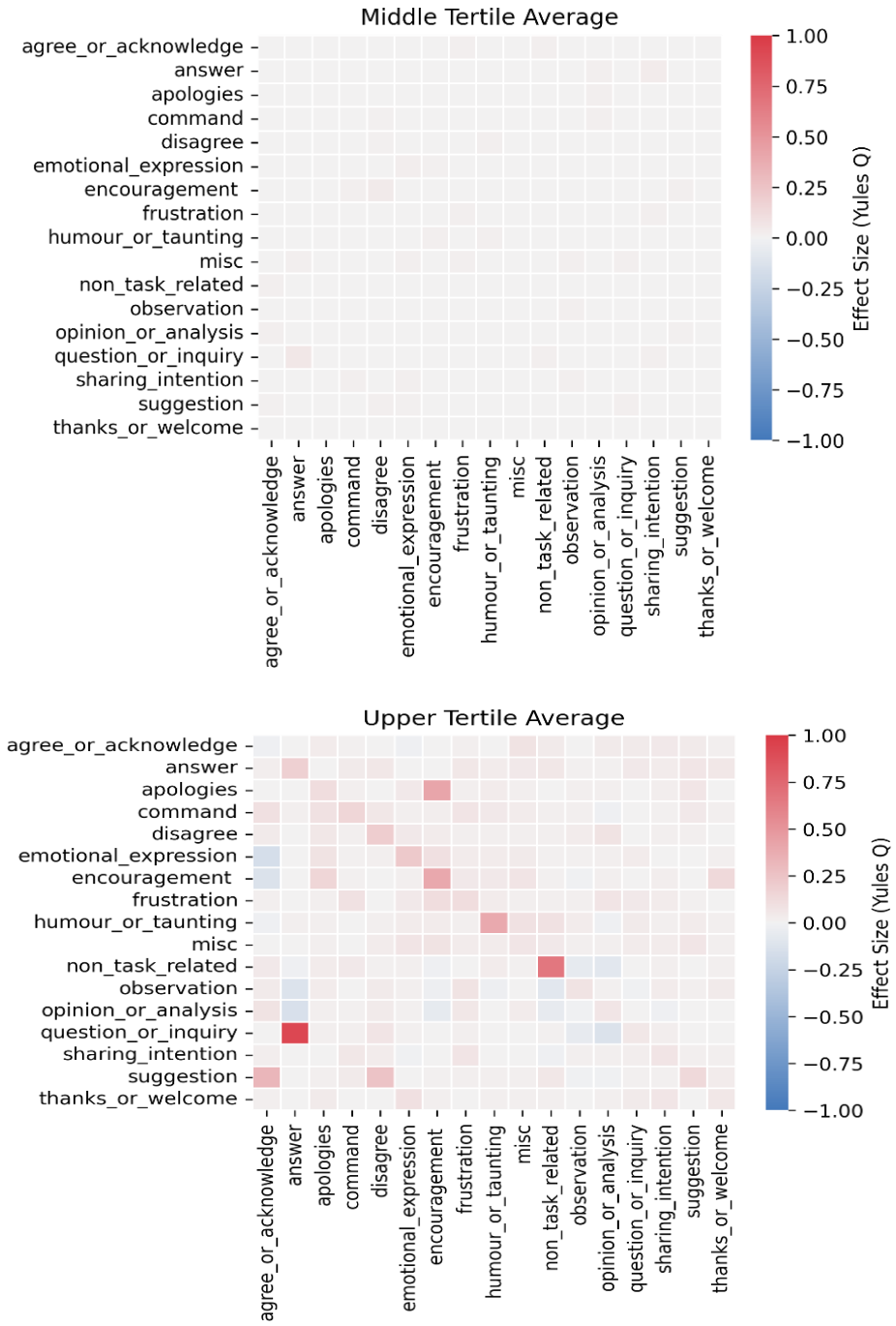

Figure 22 Comparison of communication sequences between teams with different cohesion levels.

This graph shows a comparison of the significant sequences between the teams in the middle tertile of cohesion (left) and highest tertile of cohesion (right). Sequences are read from the vertical axis to the horizontal axis (e.g., in the highest tertile of cohesion, questions (question/inquiry on vertical axis) are strongly followed by answers (on

horizontal axis). Sequences that are more likely to occur are represented by red squares. Sequences that are less likely to occur are represented by blue squares. The luminance of the squares reflects the effect size of the sequence, represented by Yules Q.

Similarly, we wanted to investigate whether sequences were different between high-cohesion and low-cohesion teams, on average. We first split the sample into tertiles based on cohesion scores. There were no teams in the lowest tertile (cohesion score < 2.3). Hence, the middle tertile (2.3 < cohesion score < 4.6; n = 3) and highest tertile (cohesion score > 4.6; n = 45) were compared. We ran the sequence analysis on each individual sample in the group and combined the samples to get a group average. Figure 22 shows the results from the analysis.

The results indicate a difference in sequences between winning and losing teams, on average. The results also indicate a difference between teams in the upper tertile of cohesion compared to teams in the middle tertile of cohesion, on average. However, when comparing sequences from teams in the upper tertile of cohesion with winning teams, the sequences seem to be similar. This is not unexpected since there is a strong correlation between cohesion and performance (noted in Section 5.6.1). It should be noted that we did not conduct the filtering steps outlined in Section 5.5.3.

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