Ping to Win? Non-Verbal Communication and Team Performance in Competitive Online Multiplayer Games

Alex Leavitt,[1] **Brian C. Keegan,**[2] **Joshua Clark** [1]
[1] University of Southern California, Los Angeles, California, USA
[2] Harvard University, Boston, Massachusetts, USA
aleavitt@usc.edu, bkeegan@acm.org, joshuaac@usc.edu

ABSTRACT
Non-verbal communication plays a large role in online competitive multiplayer games, as team members attempt to coordinate with each other without distraction to achieve victory. Some games enable this communication through "pings," alerts that are easy to activate and provide auditory and visual cues for teammates. In this paper, we review the literature on gestures and non-verbal communication and, through an empirical analysis of 84,489 players across 10,293 matches in the popular game, *League of Legends*, illustrate ping use in multiplayer games and test the impact of ping actions on performance in teams. We show that the amount of pings depends on player role and in-game activity and that pings by players have a positive but concave relationship with player performance. These findings demonstrate the importance of non-verbal communication and interruption on the performance of virtual team members. We conclude by discussing the implications of these results for theorizing and designing sociotechnical systems that rely on users to engage in synchronous, collaborative work in shared visual spaces.

Author Keywords
Alerts; pings; non-verbal communication; interruptions; awareness; online games; MOBA; virtual teams; coordination; performance; League of Legends; e-sports

ACM Classification Keywords
H.5.3 Information Interfaces and Presentation: Group and Organization Interfaces (collaborative computing, computer supported cooperative work; synchronous interaction); K.8.0 Computers and Society: General (Games)

INTRODUCTION
How well do teams perform on high-tempo tasks within collaborative virtual environments without rich, face-to-face communication? Human-computer interaction research has explored this question for more than two decades across a variety of contexts and technologies [18, 26]. Online sociotechnical systems now provide a substantial opportunity for social scientists to test and develop new theories of organizational behavior. While sports have been used as a setting to study coordination and communication [16, 24], cooperative online games — for example, *League of Legends* — provide unique circumstances to test theories about virtual team performance, because they provide rich behavioral data in high-tempo settings with consistent rules.

Following recent calls to analyze how communication tools influence virtual team coordination [72], our study examines the role of non-verbal, communicative alerts called "pings" and their impact on performance in the popular multiplayer online battle arena (MOBA) game, *League of Legends* (*LoL*). In this game, two five-member teams attempt to destroy the opposing team's base while protecting their own. Players must not only perform specialized roles with precise skill, but they must also quickly process complex streams of information in a shared visual environment and coordinate team members' behavior to respond to opponents' play. Communication plays a crucial role in this work, but the rapid pace of the game and *ad hoc* nature of teams precludes the ability to maintain consistent communication through text or voice chat. While pings provide players with the affordance of quick, targeted communication, team members need to balance using alerts to improve situational awareness for team members with interrupting teammates' flow, disrupting focus, or overloading their attention.

In this paper, we draw on scholarship about the role of gesture and non-verbal cues in collaborative work, the dynamics of teams in multiplayer online games, and awareness and interruption in collaborative environments to develop and evaluate an empirical model of team communication and performance. We test this model by analyzing a dataset containing actions from 84,489 *League of Legends* players in 10,293 games (comprised of 102,930 individual game sessions). Using hierarchical regression analyses to control for player-, team-, and game-level performance, we find evidence of variation in use of pings by types and amount of participation; a positive relationship of ping use on some kinds of individual-level performance; and relationship between pings and lowered performance from interruption. These findings connect emerging research about team behavior in multiplayer online games with theories from linguistics, organizational behavior, and human-computer interaction, and furthermore they have implications for designing collaborative systems to support virtual teamwork.

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RELATED WORK

Team coordination in online games relies on precise communication. However, for many players, verbal communication is not possible, and these players rely on non-verbal communication cues built into games' software. Below, we review the literature related to notifications as non-verbal communication, the role of pings in the coordination of teams in multiplayer online games, and the impact of alerts on disruption of virtual team coordination.

Non-Verbal Communication

People use non-verbal communication to coordinate actions in all aspects of daily life. Examples of non-verbal communication include the use of space ("proxemics"; moving into a new location), body movements ("kinesics"; pointing at an object), touch ("haptics"; touching someone on the shoulder), gaze ("oculesics"; looking in a direction quickly), time ("chronemics"; waiting for an extended period), or artifacts ("objectics"; using a sign to direct traffic) [3].

Gestures in environments

Gestures are a form of non-verbal communication between people in each others' presence that manifests as "deliberate expressiveness" and acts in parallel with or in place of verbal expressions to add more information, to specify or correct the meaning of something being said, to create a representation of what is being discussed, to lay out spatial configurations or patterns of action, or to reference objects spatially [44]. Gestures' meanings are communicated through public and intentional actions in reference to objects in the shared visual environment. Gestures organize speakers' actions and become contextual references for the production of subsequent actions through perspective taking, reliance on common ground, and revision of shared mental models [30]. Gestures can act as "coordination devices" that integrate listeners' attention with a speaker's actions and helps develop common ground about joint action [10, 33].

Gestures may also entirely replace verbal utterances as the sole communicative action under constraints like disability (*e.g.*, American Sign Language), distance (*e.g.*, crane operations[1]), or hazards (*e.g.*, infantry signals[2]). The latter two limitations are applicable to this paper's focus on pings in games because the alert-receiving player acknowledges the sender's message through direct actions (e.g., taking up a position on the map closer to or farther from the alerted issue) rather than employing verbal acknowledgments or reciprocating with non-verbal codes over the same channel.

Computer-mediated non-verbal communication

Although computer-mediated communication like text chat lacks the rich affordances of physical or embodied communication, new forms of CMC such as video conferencing, avatar-based chat, and 3D virtual environments have introduced new multimodal cues and more embodied forms of interaction that support a greater variety of non-verbal mediated communication [8, 56]. Non-verbal cues in these systems can range from acts that the user defines (through deliberate performance and individual encoding of meaning), acts that the user adopts (pre-defined cues), or a mixed type of act that the user selects and the system encodes (blended) [2]. Examples of non-verbal cues in CMC include gaze, body orientation, and pointing in 3D virtual environments [8, 39, 57].

The differences in non-verbal communication within mediated environments can limit the successful use of collaborative systems unless they incorporate *awareness information*. Awareness is "an understanding of the activities of others, which provides a context for your own activity," and this context is used to evaluate the relevance of individual contributions to group activity and goals [18]. Groups, though, also require *awareness information*, so individuals can make sense of team members' activities and adjust their behavior accordingly [25]. In the context of shared visual spaces, actions themselves can replace verbal utterances as the primary mechanisms of establishing co-present awareness, leading to coordinated action [27, 28, 50].

However, encoding non-verbal cues into mimetic, pre-defined actions within these shared virtual environments may be seen by speakers and receivers as unnatural, because it presents actions that are normally — in a face-to-face setting — unconscious or effortless [8, 22]. Users employ and respond to non-verbal behaviors within virtual worlds because the common visual space enables unique and multiple kinds of monitoring, making actions mutually comprehensible [39, 56]. Cooperation within virtual worlds and online games unfolds through shared attentiveness, responsiveness, functional identities, focus, and objectives to action within a shared visual space [75].

Non-verbal cues have the potential to improve performance, especially in virtual spaces where poor communication between team members can pose real problems for performance and success. The combination of environmental gestures, mediated non-verbal communication, and awareness during collaborative tasks motivates our primary research question:

> **RQ**: How does the use of non-verbal cues in a collaborative online game impact virtual team members' performance?

While prior research on non-verbal communication in computer-mediated contexts has used laboratory experiments, system evaluations, and simulations, this paper makes a methodological contribution by using a database of observational records to understand 84,489 players' non-verbal communication in practice. As we detail in subsequent sections, multiplayer games like *League of Legends* provide ideal research settings to collect granular, large-scale, and anonymized data about the relationship between mediated gestures and team performance in the context of their natural use on collaborative tasks.

[1]"Hand Signals for Crane Operation." U.S. Occupational Safety & Health Administration. **https://www.osha.gov/dte/grant_materials/fy10/sh-21009-10/Hand_Signals_Cranes.pdf**
[2]"Visual Signals". U.S. Army Field Manual 21–60. **http://armypubs.army.mil/doctrine/DR_pubs/dr_a/pdf/fm21_60.pdf**

Communication and Performance in Online Games

The formation of multi-person teams is a common feature in online games [65]. The size and duration of these teams can ranges from small transitory "pick-up groups" to established guilds with durable institutions [74], depending on the affordances and tools provided by the game's code. Competitive games generally feature two distinct team types. The first are transitory, semi-random, pick-up groups formed by the game's matchmaking algorithms. Each team consists of players of roughly the same skill and experience who are paired up against another comparable team. A smaller subset of players form more permanent teams, playing with the same teammates repeatedly as a cohesive unit. Within both types of teams, players assume specialized roles which influence their play and communication patterns [19]. As an example, some players may take a "support" role and focus on enhancing the efficacy of their teammates, though this role may rely on increased communication with other team members. Other roles involve controlling the map or pressuring opponents, changing the objectives and strategies of the player in question accordingly [64]. Existing research on competitive games has demonstrated two factors which increase the likelihood of a given team performing well. First, pre-existing relationships between players is correlated with improved overall performance [64]. Experienced teammates have had time to adjust to each others' play styles and develop effective systems for information exchange. Additionally, more-experienced players will develop a general understanding of the game independent of a particular team [40]. Such individual mastery improves the overall performance of a team, raising the baseline for the entire group [19].

Online multiplayer games face multiple usability challenges, such as providing appropriate communication channels, supporting player coordination, and presenting meaningful awareness information [62, 75]. A positive relationship between text chat and task performance in online games are mixed. On one hand, teams have higher performance when they communicate more frequently [35] and have more interconnected group communication networks [7]. On the other hand, players tend to use text chat for socioemotional rather than task-related content [61], and participation is influenced by early norm-setting and role-taking [14]. Because text chat can be distracting within time-constrained and competitive games [36], other modes of short, synchronous communication such as voice or auditory cues may be more effective than text chat [45]. Prior work has examined the role of multi-modal communication channels within multiplayer online games, finding an increase in team relationship strength when using voice [73] or when considering auditory cue awareness for coordination [41]. Still, voice chat can be confusing for players [32], and game sounds (alerts, sound effects, and music) have mixed effects on team performance within MOBAs specifically [59].

Audio and text are not the only communication channels available. Game players use virtual gestures to communicate information and provide awareness cues to each other [9]. "Cooperative communication game mechanics" enable players to share information and direct action through specific affordances that modify the shared environment, automate or standardize common communication needs, and focus attention with semantic meanings or contextual and spatial relationships [72]. As one type of affordance, pings are nonverbal alerts that help players coordinate, activated by a simple button or click. Pings are expressive, environment-modifying, and attention-focusing cues that allow players to identify locations to other team members by temporarily marking a location on their map or visual environment. These pings can be semantically rich or poor, depending on whether the game supports a variety of pings or if pings are only used in specific contexts. We describe the affordances of pings specifically within *LoL* in greater detail later in the paper.

Much of the research examining team performance in MOBAs like *League of Legends* and *Defense of the Ancients 2* (*Dota 2*) has emphasized the importance of team composition [63], role diversity [64], sequential combat patterns [77], player skill [19, 60], cumulative experience [31], and optimizations of routines [5] as crucial features. Other research has focused on psychological [42], social [66], and cultural [40] contexts within which MOBA games are played. We take into account many of these factors in this study with a variety of control variables.

As is the case with other temporary and self-organized teams [6], players strategize around pre-defined roles within a "meta-game" of how they expect the opposing team to use particular types of playable characters in particular configurations [17, 48]. Player roles in MOBAs vary in terms of their mobility across the map (*e.g.*, the jungle) or susceptibility to ambushes (*e.g.*, the mid lane). The need for information awareness especially occurs within *local* spaces, where one has primarily responsibility, or within *peripheral* working spheres, where others integrate teammates' contributions [29, 51]. These roles vary in their level of situational awareness [69], which imposes different expectations about how other team members should communicate threats and opportunities to augment team members' awareness in their respective areas of the game environment. Given these contexts, we hypothesize that:

H1a: Individuals' amount of pings will differ based on team role, social relationship, and skill.

H1b: Individuals' amount of pings will vary with individual performance.

H2: An individual sending more pings will have higher levels of performance.

Flow and interruption overload

The need to balance information awareness with the disruptive effects of interruptions is a common dilemma for collaborative activities. Task interruptions can arise from the *external* environment (*e.g.*, social interactions) or from *intrinsic* motivations (*e.g.*, information seeking). Interruption overload —

as a kind of information overload, fatigue, or anxiety — has a variety of causes, symptoms, and countermeasures that operate at multiple levels [21]. Interruptions can influence switching propensity [13, 70], performance [1], recovery time [37, 38], decision making [71], and affective states [52, 78]. Moderating the immediacy, channel, frequency, costs, and social contexts of interruptions based on users' attention all have potential for reducing or recovering from these adverse impacts [15, 37, 38, 55].

Interruption is a critical problem in completing tasks, especially in sociotechnical systems where communication can be more difficult. Online games are rewarding experiences for players when the challenges they face in the game are closely matched with their skill to solve them [47], a more general psychological phenomenon known as "flow" [12]. In a competitive game, team coordination can require players to engage in tasks that break their concentration, involve ambiguous situations, lack immediate feedback, or participate in actions over which they have no control [11]. Also, communication tasks in a game inherently involve "subject-subject" interactions between players but also "subject-object" interactions, when the player must deal with the user interface designed for the game [75], and figuring out the system to communicate may introduce additional confusion. These challenges can overwhelm a player's ability to apprehend and respond to developments in their role [4], breaking their "flow" and lead to anxiety, stress, and loss of focus that reduces their performance [21].

For example, pings can interrupt the "work" of monitoring opposing team activity and impose cognitive overhead on team members. The player issuing the ping must break their attention to the task at hand, map their message into an appropriate ping type, spatially locate the issue so as to be relevant to other team members, and evaluate whether this message was received and properly decoded by changes in the target teammates' behaviors. These alerts can also break the attention of the other team members who need to decode the ping type and location, evaluate the notification against their ongoing information processing, decide how to change their behavior, and then take additional necessary actions. Therefore, we also hypothesize that:

> **H3**: Pings have a concave relationship with performance: an individual sending more pings will have higher levels of performance; after a point, sending more pings leads to lower levels of performance.

DATA AND METHOD

For this study, we used a set of game log data from the popular online video game, *League of Legends* (*LoL*). *LoL* is currently published by Riot Games and is the most popular multiplayer online battle arena (MOBA) and the most-played PC game in the world, with more than 27 million daily users in 2014.[3] *LoL* has also become one of the most popular "e-sport" games: its 2014 World Championship attracted more than 32 million online users and $2.3 million in prize money.[4]

The classic MOBA battle arena[5] in *LoL* is a square map with three primary "lanes" (top, middle, and bottom) connected by a central "jungle" area containing special bonuses as well as opportunities to ambush opponents. Individual players control a single unit, called a "champion", that varies significantly in abilities. Each team of five selects champions for specific complimentary offensive, defensive, and support roles, and the team takes initial positions across the four areas (usually one in top, one in mid, two in bottom, and one in jungle). All champions are initially weak, but they accumulate wealth and experience by killing other champions, defensive structures, and waves of non-player "minion" characters. Players use these rewards and experience to purchase items to unlock more powerful abilities that give them advantages. The game ends when either your team's or your opponent's home base is destroyed.

Pings in League of Legends

LoL players can communicate with each other with both the built-in chat tool as well as a built-in ping feature. In its description of the feature, Riot Games emphasizes that pings are designed as non-verbal gestures that players can use to quickly communicate common-but-specific messages to team members without the need for text chat [67]. When a *LoL* player uses a ping, four things occur for all players on the team. First, the icon of a ping is marked on the field-of-view (Figure 1). Second, the ping will show an alert on the mini-map so that players in more-remote locations are aware. Third, an automated message appears in the text chat area telling other team members the type of ping and user issuing it. Fourth, the ping makes a distinctive alert sound.

Players can activate the "basic" or "caution" pings with keyboard hotkeys or use the "Smart Ping Menu". Players can place pings anywhere on the map and can rapidly repeat pings if they wish. The use of different graphics, sounds, and colors was designed to ensure players will "never be confused about which ping just went out" [67]. With only a single or two versions of a ping, messages could be semantically ambiguous as tactical, spatial, or deictic information and could still require chat communication to establish common ground. The introduction of six distinct types of pings in *LoL* points to an increased reliance on these non-verbal cues for coordinating behavior in a shared virtual environment. These actions clearly map onto classifications that emphasize the cross-cultural importance of gestures for interpersonal control (*e.g.*, "stop!"), declaring one's current state (*e.g.*, "Help me!"), or evaluative descriptions of others' actions and appearances (*e.g.*, "He's dangerous") [43].

[3] "League Players Reach New Heights in 2014." Riot Games.. `http://www.riotgames.com/articles/20140711/1322/league-players-reach-new-heights-2014`

[4] "League of Legends, E-Sport's Main Attraction." (2014) *The New York Times*. `http://www.nytimes.com/2014/10/12/technology/riot-games-league-of-legends-main-attraction-esports.html`

[5] *LoL* offers several game styles and maps, but the "Summoner's Rift," 5-versus-5 map is the most popular as well as the most representative of the general MOBA genre.

Figure 1: The appearance of the danger ping in a player's field-of-view.

Figure 2: The appearance of a danger ping in the mini map.

Dataset

We used server log data collected from 41,518 total games, scraped from the game client and made available via the (now defunct) website Riftwalk.gg.[6] The games chosen for analysis were limited to those from North America that took place on the 5-versus-5 "Summoner's Rift" map and lasted between 20 and 50 minutes. Our dataset resulted in 10,293 games, comprising of actions by 84,489 players in 102,930 play sessions, and which were played between July 27, 2014 and September 10, 2014. Each game is comprised of metadata for each player, from in-game interactions (*e.g.*, kills) to individual and team achievements (*e.g.*, gold earned). Location data for each player, taken at every five seconds during each match, were used to detect roles for each player based on their position in specific lanes. The data also contain instances of communication pings per player, though the dataset's logs do not contain any text chats between teammates. To measure performance, although the data contains a binary variable for whether a team won or lost, we preferred to focus on metrics of performance (kills, assists, deaths, and gold per minute). All identifiable player information was anonymized.

[6] "Watch 10,000 League of Legends Games in 30 Seconds." (2014) *The New York Times*. `http://www.nytimes.com/interactive/2014/10/10/technology/league-of-legends-graphic.html`

Statistic	Mean	St. Dev.	Min	Max
Total Ping Clicks	3.3	4.7	0	92
Total Non-Spam Pings	2.5	4.3	0	88
Total Kills	5.9	4.6	0	45
Total Assists	8.6	5.8	0	46
Total Deaths	5.9	3.2	0	30
Gold per Minute	185.0	66.1	0	511.7
Max Level	15.1	2.5	0	18
Skill	1485.8	392.8	149	3082
Played with Group	0.1	0.2	0	1
Length in Minutes	33.0	7.5	20.0	54.8

Table 1: Player-level variable summary statistics. (N = 102,930)

Variables

All variables are summarized in Table 1 and defined below:

We operationalize performance, from our hypotheses, with four constructs:

Total Kills : Count of the player killing another player.

Total Deaths : Count of the player's deaths by another player or non-player character (both are included, because a death results in the player removed from the game for a set amount of time).

Total Assists : Count of the player's assistance in killing another player. An assist is defined as hitting or contributing to an attack (e.g., a spell) on the target player in the last 10 seconds before the target's death.

Gold per Minute : Count of total gold (reward based on number of kills, assists, and other actions during the game) accumulated by the player divided by total length of match in minutes.

We then include a variable for pings:

Non-Spam Ping Count : Count of total pings[7] made by the player. We defined "non-spam" pings by calculating if each ping click occurred within a 2-second window of each other (if so, they were collapsed into one ping action). We explain removal of spam pings in a later section.

Finally, we include other variables as additional independent variables and as controls:

[7] We only have logs of "basic" and "other" ping events and cannot disambiguate ping types.

Player Zone-Role : Category of the player's primary zone ("lane" or "jungle") on the map. We include this variable because communication may change between player roles. We defined zone by calculating X and Y coordinates on the map, using 41,293,520 player locations (taken every 5 seconds during each match). Using the locations in the first 5 minutes of each game, we summed these locations per player and (excluding the "home base") took the highest-occurring zone as the player's zone-role.

Skill : Measure of player rank (used to combine players into teams). League of Legends maintains a score for every player based on prior wins and losses (similar to ELO ranking for chess). This measure combines prior number of games with success ratio to provide a relative measure of skill, allowing us to control for prior experience.

Played with Group : Category of whether or not the player played with a defined group or entered into the team as a solo individual. *LoL* allows players to enter into a game with predefined teammates, allowing us to control for players with prior experience together.

Length in Minutes : Total minutes for which the game lasted.

Team ID : ID for the player's team in a match. Team 100 is Blue (starting on the bottom of the map) and Team 200 is Purple (starting on the top of the map). Used as a hierarchical variable.

Game ID : ID for the player's match. Used as a hierarchical variable.

Method

The data were stored in a PostgreSQL database, and we used R for data cleaning, statistical analysis (specifically the "lme4" package), and visualization.

To answer H1, we used descriptive statistics to illustrate player differences and a hierarchical negative binomial regression to predict ping count from player attributes. This allowed us to say which player variables impacted the count of pings.

To answer H2 and H3, we used a hierarchical linear regression to predict measures of performance (number of kills, assists, deaths, and gold per minute) and included terms for ping count and squared ping count. This allowed us to say controlling for all other variables if using pings was related to performance on a linear or curvilinear trend.

RESULTS

To provide context for the first hypothesis, we analyzed the empirical use of pings in *LoL*. Overall, players' uses of multiple ping clicks is not particularly common: 46.32% of players clicked a ping button *one or fewer* times per match.

However, some players do click multiple times per game. To accurately describe when pings are used to notify about an event in the game, we need to account for variation in use cases. Sometimes, players will rapidly click the ping button, and teammates will notice these rapid bursts of activity as a moment to pay attention. In our analysis, we wanted to avoid over-counting ping clicks when they are rapidly fired during an event, because we are mainly concerned about moments of coordination between team members. By identifying and removing repetitive ping clicks, we are able to filter noise in the data, in cases where these rapid notifications provide no new information to teammates. In our regression analysis, we reduced the number of "spam" pings by taking all pings that occur within a 2-second window (the time period within which many ping clicks clustered) of each other and collapsing them into single events. This led to a reduction in 27.79% of total pings across all games.

	Dependent variable:
	Total Non-Spam Pings
Total Kills	1.162^{***}
	(0.010)
Total Assists	1.206^{***}
	(0.007)
Total Deaths	1.059^{***}
	(0.006)
Gold per Minute	0.990^{***}
	(0.012)
Zone-Role: Bottom Lane	0.993^{***}
	(0.015)
Zone-Role: Jungle	1.611^{***}
	(0.016)
Zone-Role: Mid-Lane	1.218^{***}
	(0.016)
Max Level	1.050^{***}
	(0.013)
Skill	1.061^{***}
	(0.007)
Played with Group	0.436^{***}
	(0.031)
Length in Minutes	1.286^{***}
	(0.013)
Team ID	0.997^{***}
	(0.010)
Constant	1.776^{***}
	(0.014)
Observations	102,930
Log Likelihood	−199,837.543

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$
Reference category for zone-role is Top Lane.
Reference category for Played with Group is playing without a defined group.
Reference category for Team ID is Blue Team (starting on bottom).

Table 2: Negative binomial mixed-effects model using team and game as random effects predicting count of player pings. Coefficients are exponentiated betas.

Pings and Activity

Hypothesis 1 predicted that the number of pings an individual issues would vary as a function of their role, relationships, and skill. To look at the relationship between pings and a

	Dependent variable:			
	Total Kills	Total Assists	Total Deaths	Total Gold per Minute
	(1)	(2)	(3)	(4)
Total Non-Spam Pings	0.039^{***}	0.085^{***}	0.024^{***}	-0.004
	(0.003)	(0.004)	(0.004)	(0.003)
Total Non-Spam Pings Squared	-0.014^{***}	-0.030^{***}	0.003	0.0004
	(0.003)	(0.004)	(0.004)	(0.002)
Total Kills		-0.414^{***}	0.087^{***}	0.691^{***}
		(0.004)	(0.005)	(0.002)
Total Assists	-0.139^{***}		-0.162^{***}	0.073^{***}
	(0.002)		(0.003)	(0.002)
Total Deaths	0.092^{***}	-0.057^{***}		-0.093^{***}
	(0.002)	(0.003)		(0.002)
Gold per Minute	0.903^{***}	0.138^{***}	-0.221^{***}	
	(0.002)	(0.005)	(0.005)	
Max Level	-0.218^{***}	0.198^{***}	-0.094^{***}	0.546^{***}
	(0.004)	(0.005)	(0.006)	(0.003)
Zone-Role: Bottom Lane	0.094^{***}	0.681^{***}	0.017^{*}	-0.004
	(0.005)	(0.005)	(0.007)	(0.004)
Zone-Role: Jungle	0.033^{***}	0.401^{***}	-0.058^{***}	0.012^{**}
	(0.005)	(0.006)	(0.007)	(0.004)
Zone-Role: Mid Lane	0.152^{***}	0.289^{***}	0.141^{***}	-0.007
	(0.005)	(0.006)	(0.007)	(0.004)
Skill	-0.117^{***}	0.010^{*}	-0.001	0.103^{***}
	(0.002)	(0.005)	(0.005)	(0.002)
Played with Group	0.0005	-0.045^{*}	-0.201^{***}	-0.011
	(0.007)	(0.020)	(0.022)	(0.007)
Length in Minutes	0.370^{***}	0.456^{***}	0.611^{***}	-0.484^{***}
	(0.003)	(0.006)	(0.007)	(0.003)
Team ID	-0.015^{***}	-0.032^{***}	0.014^{*}	0.012^{***}
	(0.003)	(0.009)	(0.006)	(0.003)
Constant	-0.067^{***}	-0.390^{***}	-0.019^{*}	-0.005
	(0.004)	(0.007)	(0.008)	(0.004)
Observations	102,930	102,930	102,930	102,930
Intraclass Correlation (Team)	0	0.0123	0.203	0
Intraclass Correlation (Team & Game)	0.0268	0.468	0.339	0.0679
Log Likelihood	−75,363.152	−110,360.796	−120,944.515	−61,689.250

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Reference category for zone-role is Top Lane.
Reference category for Played with Group is playing without a defined group.
Reference category for Team ID is Blue Team (starting on bottom).

Table 3: Linear mixed-effects hierarchical regression using team and game as random effects predicting player-level performance. Coefficients are standardized betas.

player's role and activity, we modeled a negative binomial regression predicting each player's total ping count in a game, controlling for variables such as skill and match length. We found support for both Hypotheses 1a and 1b.

First, we examined each player's role, based on the calculated zone-role, using the Top Lane as a reference category. Players in the Bottom Lane had a lower log of expected ping counts than Top Lane players (Exp(β) = 0.993, p< 0.01). Mid Lane Players had a higher log of expected ping counts (Exp(β) = 1.218, p< 0.01). Jungle players had the highest log of expected ping counts (Exp(β) = 1.611, p< 0.01). Players who played with a pre-defined group had a much lower log of expected ping counts (Exp(β) = 0.436, p< 0.01). Players with higher maximum level (Exp(β) = 1.050, p< 0.01) and higher skill (Exp(β) = 1.061, p< 0.01) also had higher log of expected ping counts.

Second, we examined each player's match activity. Players who have more kills (Exp(β) = 1.162, p< 0.01), assists (Exp(β) = 1.206, p< 0.01), deaths (Exp(β) = 1.059, p< 0.01) had higher log of expected ping counts. Players with a higher gold-per-minute ratio had a lower log of expected ping counts (Exp(β) = 0.990, p< 0.01).

Given the significant findings in this regression, H1a and H1b were supported.

Pings and Linear Performance
Hypothesis 2 predicted a positive relationship between individuals' sending pings and their in-game performance. We defined performance by the number of kills, assists, deaths, and gold per minute achieved by a player, controlling for other performance variables as well as player roles, skill, and game length. More kills, assists, and gold per minute, along with fewer deaths, should reflect high levels of player performance. The estimates reported in Table 3 are standardized coefficients to aid comparability of effect sizes across different base units.

There is mixed evidence of a positive relationship across all four of the performance variables. Players who send more pings get more kills (β = 0.039, p< 0.01) and more assists (β = 0.085, p< 0.01), but they also die more (β = 0.024, p< 0.01). No significant effect was observed on pings and individuals' average gold per minute rate (β = -0.004, p> 0.05). Comparing the magnitude of these estimates to the other control variables, a standard deviation change in the number of pings players used has a weaker effect on performance than changes in other behaviors. Because the results varied for each regression, Hypothesis 2 is partially supported.

Pings and Curvilinear Performance
Hypothesis 3 predicted a concave relationship between squared ping count and performance. Again, we defined performance by the number of kills, assists, deaths, and gold per minute achieved by a player, controlling hierarchically for team and game. The model reported in Table 3 shows the results from these regressions.

We again find mixed evidence for the linkage between ping use and performance. More pings result in a concave relationship with number of kills (β = -0.014, p< 0.01) and number of assists (β = -0.030, p< 0.01), but there is no significant curvilinear effect observed for either total deaths,(β = 0.003, p> 0.05) or total gold per minute (β = 0.0004, p> 0.05). Again, comparing the magnitude of the significant estimates to estimates for other variables and models, the effects of pings squared are relatively small. Because the results varied for each regression, Hypothesis 3 is partially supported.

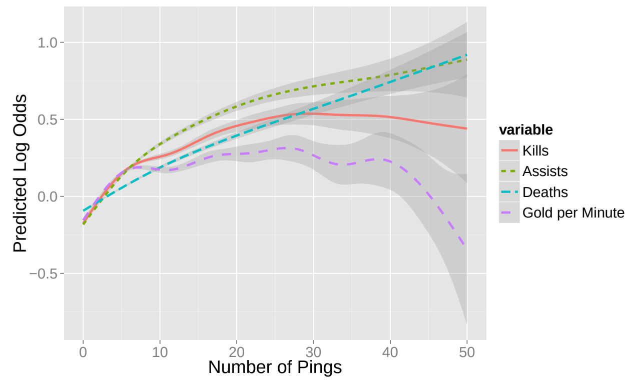

Figure 3: Predicted log-odds for each regression model in Table 3 based on the number of pings per player using GAM smoothing and 95% confidence intervals.

DISCUSSION
We analyzed a large-scale observational database of "pings" in 10,293 *League of Legends* matches to test the relationship between this unique form of non-verbal communication and individual performance. We found strong evidence that ping amounts differed based on players' roles and activity on the team but found mixed evidence that pings had significant — and especially large — effects on individual players' performance. Below, we discuss these findings in more detail; identify implications the results have for theory and design; and examine limitations and opportunities for future work below.

Pings and Participation
Controlling for other variables, specific roles were more likely to send pings to their team more often. This result suggests that collaborative team communication in high-tempo situations relies on the context of individual roles within the team. Namely, depending on where a player is located within the environment (*e.g.*, jungle role, which roams around the central area of the map), they have more visibility into the opposing team's locations and actions, and therefore part of this role's core purpose is to warn teammates. As Ferrari claims, "Players may have a basic idea of where an opponent might be, but they are expected to declare a blind spot or confusion whenever they encounter one. The jungler is often tasked with reconnaissance into the opponent's territory, in order to gauge the state of the other team and communicate back to others" [23]. This vision advantage is not unique to the jungle role: other roles, such as mid-lane, also see more areas of the map than bottom or top lane, leading to a stronger

incentives to employ pings to communicate with team members. Perhaps unexpectedly, Bottom Lane, where two players cooperate, resulted in less pings compared to Top Lane, suggesting that players who are co-located may not need the affordances of alerts, and that alerts may only be especially useful for players a certain distance apart.

While the literature describes teams who play together as having better performance and communication, players who play with a pre-defined group appear to use less pings than those who do not. Part of this result may reflect less frequent need to alert teammates to issues on the map because players are more aware of others' actions. Also, the result may be related to the reality that pre-defined teams use alternate communication channels like 3rd-party VOIP software.

Pings and Performance

As we demonstrated in Hypothesis 2, pings had a linear relationship with some measures of player performance. Direct offensive actions like kills and assists had a positive relationship with pings in this trend. We surmised that pings used in a defensive manner — as a warning to avoid being killed by enemies — would have a negative relationship with bad performance (ie., deaths). However, surprisingly, deaths were positively related to pings. This result may be a side effect of other variables having impact on deaths, but more research is needed to tease apart this relationship, such as deeply examining how pings are used in moments of trouble. Finally, pings were also — surprisingly — negatively related to gold per minute. This result may be due to distraction and its impact on the rate that players are receiving awards, however it is difficult to assess this granularity with a static (rather than longitudinal) model like the one we are using. Still, the curvilinear effect of alerts on performance remains a critical factor in performance, which we discuss below.

As demonstrated in Hypothesis 3, pings had a non-monotonic and concave relationship with — again — direct offensive actions (kills and assists; see Figure 3). Because pings can be useful in specific moments to coordinate precise actions between teammates, it makes sense that alerts would aid offensive actions, up to a point where they merely get in the way. However, the use of defensive notifications to avoid deaths — which was not significant in this model — suggests other factors mediated the relationship between communication and defensive performance (or perhaps were focused tasks for only accumulating rewards, ie., gold). As we discuss below, these models only account for the creation of non-verbal gestures but not their reception. In the context of responding to immediate threats to your champion or "farming" for minion wealth, we might see effects on the recipients of these cues.

Implications for Theory and Design

Our findings contribute to both emerging literature about collaboration in multiplayer online games and game analytics [20] as well as existing scholarship about virtual team processes, communication, and work interruptions. Pings are important for a variety of different team activities: team members need to plan and articulate tactics (transition processes); monitor individual and team progress against goals and coordinate to act on discrepancies (action processes); and manage conflicts and maintain cohesion (interpersonal processes) [53]. The adoption and performance effect of these non-verbal cues mirrors the use of environmentally-coupled gestures in complex settings that demand more rapid and coupled forms of expression.

Pings are likely employed for a variety of uses, but they are fundamentally a mode of conveying awareness information within a team operating within a shared visual space [18]. Team mental models, transactive memory systems, and collective intelligence are examples of team cognition reflecting the shared understanding about a task environment and members' knowledge [46]. These cognitive representations are important for team members to predict system states and make inferences about system behavior [68]. The more models that team members share in common, the better they will be able to develop collective intelligence [76] and processes to implicitly coordinate their work, especially in highly dynamic environments such as (simulated) combat [34, 54]. MOBAs like *LoL* provide compelling settings to evaluate the development in teams assembled under different conditions, their accuracy against dynamic but objective criteria, their revision under stress and interruption, and their effect on coordination processes such as communication. The results from this study help support a lot of this literature, but they also suggest that precise moments of non-verbal communication can have subtle effects on individual performance within teams. Further, the design of non-verbal communication may have specific types of impacts on the sociotechnical system, and we should consider how the adoption and uses of these cues propagate across the communities that use sociotechnical platforms and environments for team work.

Having the ping affordance designed into the game system provides players with a variety of options for quick, concise communication, but how can they be better designed and integrated into competitive online multiplayer games? First, we suggest that game designers can pay more attention to how alerts impact attention, flow, and distraction. Many players in the *League of Legends* community complain about players who spam pings, and they have asked multiple times in various channels for ways to mute players who rapidly repeat pings in an unhelpful way.[8] Designers should focus carefully on how the affordances they provide to players can be helpful or detrimental in subtle ways on player performance.

Second, we suggest that game designers focus on the design of meaning and intended use for direct communicative actions. *League of Legends* currently offers six different types of pings, but the "basic" alert is the most commonly used ping type in our dataset, making up 61.7% of all ping clicks. Given that five additional pings make up less than 40% of ping clicks suggests that the design of activating alerts is not fluid enough for the variety of ping styles or basic pings satisfy the basic need for an auditory, visual, and environment-marking alert.

[8]For example, "Riot PLEASE can we turn off someone's pings?" **https://www.reddit.com/r/leagueoflegends/comments/2z4ic6/riot_please_can_we_turn_off_someones_pings/**

Further research should focus on experimentally testing the impact of types of pings on player behavior and cognition.

These design changes are particularly important given the overall prevalence of 'spam' pings within the analyzed games. With 23.79% of all pings observed coming withing 2 seconds of each other, there appears to be a strong incentive to use the ping function in bursts. This may be a mechanism developed by players to increase the visibility and urgency of their communication to their teammates. An alternative design implementation which designers may wish to consider given the results of this study is a mechanism to allow pings to vary in intensity or size. This allows players to say more with fewer pings and allows high-salience communication to be seen and recognized without resorting to repeated use of the ping feature. By giving players one ping with a higher degree of granularity in intensity and visibility as opposed to six equally visible options, it may be possible to reduce spam and increase alerts' impact on team coordination and success.

Limitations

There are some limitations to this paper that should be mentioned. First, we could not disambiguate *types* of pings at this stage in the analysis. It would be helpful to study how different types of communication cues impact different types of actions (e.g., a call for help leads to fewer deaths, while an enemy location ping leads to more kills).

Second, our study does not incorporate a longitudinal sample of the same players across multiple games. Therefore, we could not look at individual differences in ping use and performance across multiple matches. Further, we do not know each player's prior experience with using alerts, so we cannot determine how prior communication experience impacts player's current pings and performance.

Finally, the sample for our data is large, but it only represents one implementation of pings in one game. Generalizability remains a concern, and we recommend future research test non-verbal alerts across multiple online games as well as offline team games and tasks.

Future Research

This paper is a first step in understanding the impact that non-verbal communication alerts have in coordination and performance for virtual teams in high-tempo, shared visual spaces. Future research at a more-granular level could help improve our understanding of these behaviors. First, examining the differences between types of pings will help us understand how different meanings behind non-verbal cues impact team coordination and shared meaning between team members. Like other forms of non-verbal communication, ping uses are learned and adapted in response to the demands of particular task contexts. Following calls to pay attention to behavioral sequences, future work could analyze how players employ different sequences or combinations of pings to convey different meanings and how players interpret them.

Second, we could look at the impact of pings on a longitudinal level. These data include time-stamped logs for every event in a match, temporal analyses could explore whether and how pings change player behavior, how ping use varies over the course of a game, and how these influence team performance. Our modeling approach focused on the role of the ping sender, but using the spatio-temporal data of players and pings, we could also infer the intended recipient and construct directed non-verbal communication networks. The scale and granularity of the data likewise provide opportunities to employ causal inference methods like natural experiments and propensity score matching to make stronger causal claims about the influence of non-verbal communication on team coordination process and performance.

Finally, we could look at how other behaviors are impacted by non-verbal communication. Our dataset includes movement data for each player — X and Y coordinates taken every 5 seconds — so we could examine how players react to teammates' alerts based on their location and distance from other players. Crucially, we did not substantive coordination which requires understanding the combination of team member actions and temporal entrainment or synchronization [49], but communication is an important and necessary support for coordination behaviors [58].

CONCLUSION

In competitive online multiplayer games, like *League of Legends*, players must continually attend to local actions that affect them; make inferences about team members' positions and performance; anticipate their opponents' strategies; and make decisions about if and how to best communicate their awareness to team members. In this paper, we showed that virtual team members employ non-verbal communication strategies to improve their performance up to a point for certain crucial actions, after which these cues could interrupt their ability to execute tasks or communicate effectively.

This study also contributes to the current understanding of how small groups use non-verbal communication affordances that are increasingly prevalent in online games. Research has shown the relationship between fully-featured forms of communication, such as voice or text chat, and performance [73]. We demonstrate that this relationship also encompasses more transitory modes of communication such as pings. These findings suggest that researchers should continue to explore how to design varied sociotechnical features to create new cooperative communication mechanics outside of the traditional mechanisms such as text and voice [72, 57].

Sports provide ideal contexts to examine social and organizational team processes, but these metaphors break down as work becomes increasingly distributed, virtual, and temporary. Online games and e-sports offer the "best of both worlds" to understand the structure and dynamics of virtual teams. As the availability and granularity of data increases, online games will introduce more chances to study these behaviors.

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