# Effect of Different Communication Affordances on the Emergence of Collaboration Strategies in an Online Multiplayer Game

Hala Khodr, Nicolas Wagner, Barbara Bruno, Aditi Kothiyal, and Pierre Dillenbourg

School of Computer and Communication Sciences,
Ecole Polytechnique Fédérale de Lausanne, Switzerland, hala.khodr@epfl.ch

**Abstract.** In a group, the collective dynamics is governed by the interactions between individuals, which can manifest differently depending on the available means of communication. In this paper, we compare 3 conditions of communication affordances (global chat, local chat and no chat) in an online multiplayer game and investigate their effect on team performance. An experiment involving a total of 108 participants (grouped in teams of 6 players) revealed that while the three conditions allow for the emergence of different communication systems, they yield no significant difference on the time taken to complete the task.

## 1 Introduction

Collective behaviours are ubiquitous in nature, ranging from animal swarms to human crowds. In such systems, multiple agents have to coordinate and collaborate in a flexible and robust manner to achieve a shared goal. The communication between the agents is an essential factor affecting the interaction between them and therefore influencing the collective performance of the group. As a consequence, communication and its role in collective behaviours have been studied in many different domains and under a variety of perspectives.

A first lens for analysis focuses on the *medium of communication*, with verbal [14] and haptic [6] mediums being among the most commonly considered. In a collaborative virtual 2D pointing task between 2 dyads, Jinling et al. compared verbal, haptic, and a combination of both modalities. Their outcomes indicate that participants using verbal only and haptic+verbal communication performed equally well while participants using haptic only communication took more time and had longer path lengths [14]. Conversely, and quite interestingly, in a study on decision taking, haptically coupled dyads were found to solve a perceptual discrimination task more accurately than their best individual members and five times faster than dyads using verbal communication [10].

A second perspective is the analysis of the *emergence of communication* systems in collaborative tasks. An example of this phenomenon is the emergence of simple language (common code) when participants are involved in a coordination game with no common language made available in the beginning [12]. Such

a behaviour requires humans to know that communicative behaviour is indeed communicative in nature. [11] investigates this assumption through an ad-hoc designed experimental game. The authors found that the emergence of a communication system usually involves a bootstrapping process, and that this process has an impact on the final form of the communication system. Moreover, a sufficient common ground is observed to be a necessity for the recognition of signalhood, and the emergence of dialogue is seen as the key step in the development of a system that can be employed to attain shared goals. In [8], through a maze game task, the authors present how particular environmental affordances (such as the structure of the mazes) drive the emergence of different communicative conventions in otherwise identical tasks, suggesting that linguistic adaptations are highly sensitive to factors of the shared task environment.

A third key aspect is the analysis of the *effects of communication on team performance*, in organizational contexts. A meta-analysis reveals that communication quality has a significantly stronger relationship with team performance than communication frequency [7]. Although communication can be positively correlated with team performance, the advantages of communication are dependent on the task characteristics as well as the type of communication used [9].

Finally, the *scope of communication* is a crucial topic in all domains involving swarms of artificial agents, such as swarm robotics, where the locality of interactions and communication has a beneficial effect on the scalability and robustness of the system, and is thus generally preferred over the use of global communication and sensing [4]. Local communication is then further divided in 1) direct robot-to-robot communication, either using explicit messages or implicitly detecting the existence and relative location of other robots in the immediate vicinity, and 2) stigmergic communication relying on the modification of the environment (e.g pheromones) [13].

While, as the review above highlights, each of the key aspects concerning communication in collective behaviours has been extensively studied, less is known about their interplay. In an effort towards bridging this gap and further expanding our understanding of the role of communication, in this paper, we consider the above four perspectives together, specifically investigating the effect of different communication affordances (different mediums and scope) on the emergence of collaboration strategies and team performance in an online multiplayer game.

## 2 Methodology

For our study, we designed an online collaborative game where human participants interact via a robot avatar in a controlled experimental setup. Similar to HuGoS [5], our online environment can capture all the interaction details among participants throughout the game. Three versions of the game, respectively allowing no verbal communication, local verbal (chat-based) communication and global verbal (chat-based) communication among participants were designed, to allow for investigating the effects of communication medium and scope on the emerging communication system and team performance.

### 2.1 Game Design

**Game Mechanics** Our online multiplayer game is based on the Unity game engine and the Photon Unity Networking [2] package for multiplayer games. The game involves 6 players, each represented by an avatar which is chosen to be a virtual robot [15] of a unique colour and a limited field of view set to 5% of the total map size. The game's goal is to move boxes to goal positions indicated by red dots as fast as possible. There are a total of 12 boxes in the environment whose positions are not all visible to all players, with some that a player can move alone and others that require the joint action of 3 (medium boxes) or even 6 players. Players can control their avatars via the arrow keyboard keys. A player can move a box by: 1) *Pushing the box*: the player's avatar applies a repulsion force on the box when it is inside the halo surrounding the box or by 2) *Pulling the box*: the player's avatar applies an attraction force on the box when it is inside the halo surrounding the box and the SHIFT key is pressed. The game is organized in three stages. In the first stage, each player is in a room alone and must move a small box to its goal position to unlock a door and access the second stage. In the second stage, three players are in the same part of the environment, and they must move together two medium boxes, while the three others have the same task in another part of the environment. In the third stage, all six players are in the same space and must move two large boxes to their goals.

**Game Deployment** The game is deployed on WebGL and accessible at https://ants-cellulo-game.web.app. The advantage of using WebGL is that all files are hosted on the website, thus allowing players to play the game via their browsers, with no local download or installation needed. The game data we log include: the positions and the ping of all movable objects in the game, the chat messages, the timer. The data is logged every tenth of a second and uploaded to a Firebase storage [1] every 1 minute. The game is standalone, self-explanatory and can be played without the intervention of an experimenter.

**Communications Affordances** We implement three versions of the game, exclusively differing from one another in terms of the communication affordances provided to the players:

1) *Global Chat:* In this condition, a chat is included in the game. All players can communicate with everyone else by typing and receiving messages.

2) *Local Chat:* In this condition, only the players who are in the neighbourhood of the sending player can receive the message. On the top of the chat box, each player can see with whom they can communicate. The communication range is set to be 20% of the dimension of field of view.

3) *No Chat:* In this condition, players cannot communicate through chat.

### 2.2 Experiment Design

We designed the study as a between-groups experiment, with the communication affordance as manipulated variable (thus yielding the three conditions described

in Section 2.1) and team performance (here intended as the time taken to complete the task) as main outcome variable. The study[1] involved 108 participants recruited via Prolific [3] [2], an online recruitment platform. They self-organized in teams of 6 as described in Section 2.1 and the teams were split equally and randomly across the three conditions, thus yielding 6 teams per condition. We collected age, gender, major and degrees as background info of the participants. The mean age of all participants was 24.8 years old (SD =5.9) with 39 females, 67 males and 2 others. The participants included 44 who finished high school, 33 with a Bachelor degree, 26 with Masters, 4 with PhD and 1 other.

## 3 Results

We compare quantitatively the teams' performance in the three conditions in terms of their time of completion. To complement the statistical analyses correlating chat data with team performance, we implemented a replay tool allowing us to perform qualitative observation of players' behaviour during the game.

### 3.1 Effects of Communication Affordances on Team Performance

The mean time to complete the task, across all conditions, was 17.2 (+/- 4.5) minutes. The fastest team took 9.6 minutes and the slowest one 25.5 minutes. Although the Local condition has the lowest average time among the three conditions, a Kruskal Wallis[3] test shows no significant difference in performance among the three conditions (df = 2, H= 3.94, p = .14). This result is interesting as it contradicts the common-sense hypothesis that having a (global) communication would lead to better performance. While representing more than 100 participants, this analysis (which is done at team level), actually only accounts for 6 data points per condition: collecting more data in future studies will thus be crucial to either confirm this result (i.e., the lack of an effect of the communication affordance on performance) or reveal significant differences (e.g., between the local condition and the others).

### 3.2 Emerging Communication System Analysis - Global Condition

Although no direct correlation was found between communication affordance and team performance, a deeper analysis on the communication type which emerged in each condition provides useful insights on the possible causes of that result.

First of all, in the Global condition, a significant positive correlation (Spearman's $\rho$ = .94, p = .005, power = .9) is found between the total number of messages sent during the game and the time taken to complete the task. In

[1] This study was approved by our institutions Human Research Ethics Committee with reference number No 022-2021

[2] The average reward was set to 6 £/hr. A bonus incentive was given to groups who finish the fastest.

[3] chosen since the normality assumption of the data is not satisfied


(a) Global Condition (b) Local Condition

Fig. 1: Wordcloud analysis of the messages shared over chat.

other words, better performing teams (low time) send less messages over chat. At the same time, no significant correlation is found between the chatting frequency (i.e. number of messages sent per minute, on average) and the time taken to complete the task. These results suggest that (1) chatting more doesn't seem to help complete the task faster and rather (2) teams seem to chat "while" playing, rather than "to" play, thus sending more messages when they take longer to finish the game. In synthesis, global communication doesn't seem to have an impact on the teams' ability to coordinate actions and perform the task better.

To complement the above analysis on the volume of the messages, we also analyzed their content. Fig. 1a shows the word cloud of all chats in the Global condition. The two most recurrent words are "need" and "push". The next recurrent words are "one", "left", and "pull". This shows that the players mainly use the chat to ask for help ("need", "one"), or give orders for the actions to be done related to the game ("push","pull") and agree on directions ("left").

### 3.3 Emerging Communication System Analysis - Local Condition

The total number of messages shared by teams in the Local condition is significantly lower compared to the Global condition (ttest: t[10] = -2.3, p =.04, Cohen-d = 1.33), thus suggesting that this communication modality, by design, induces a smaller volume of messages to be shared.

Contrary to the Global condition, no significant correlation is found here between the total number of messages sent during the game and the time taken to complete the task. At the same time, no significant correlation is found between chatting frequency and completion time either. Quite interestingly, however, a median split reveals that the 3 top performing teams are also the ones with the smallest overall number of messages sent as well as the lowest chatting frequency.

These results, somewhat hinting at the importance of sharing "the right information at the right time" motivate us to look into the timing of the messages.

| | Sender | Message | Receiver(s) |
|---|---|---|---|
| Example 1 | green | its stuck | red |
| | red | pull with shift | green |
| | green | oh .. | |
| Example 2 | yellow | from the top | orange, purple |
| | purple | can't fit | yellow, orange |
| | yellow | and then left to right | orange, purple |
| | purple | isn't it better to push to left from the right... | yellow, orange |

Table 1: Examples of chats initiated in response to an event/conflict

By comparing the game events with the chat messages, we notice two trends concerning when a chat is initiated: 1) Prior to acting, e.g. before moving a box or going on search for the goal position/missing players. 2) In response to certain events, e.g. to help a player or solve a conflict. Some examples are shown is Table 1. On average, teams had 2.3 chats per game initiated prior to acting and 2.8 initiated in response to an event/conflict, with the difference between the two not being significant. Concerning the content of the messages, Fig. 1b shows the word cloud of all chats in the Local condition.

### 3.4 Emerging Communication System Analysis - No Chat Condition

In this condition, communication is only possible implicitly, via the movement of the players' avatars. The qualitative inspection of the games' replays allowed us to identify a number of emerging behaviours and communication mechanisms.

1) "Oscillating behaviour": A player moves their avatar back and forth, in a way which we hypothesize to be an indication of the direction in which they want to go (Fig. 2a).

2) Once together, players stay and navigate together (Fig. 2b).

3) "Calling behaviour": A player moves close to another player, stops, then moves, to signal to the other player to follow them (Fig. 2c).

4) "Local voting system": this behaviour is particularly noticeable when the 6 players need to decide which of the two large boxes to move first. If divided between the two boxes, players in the minority group tend to go and join the majority around the other box (Fig. 2d). This behaviour also appears when choosing in which direction to move the box. Each player chooses one side of the box and they eventually all converge to a same side.

## 4 Conclusion and Future Work

In this paper we study the effect of different communication affordances on a collaborative task to better understand the role played by communication medium and scope on multi-agent coordination and, concretely, the emergence of communication systems and team performance. The task was developed as

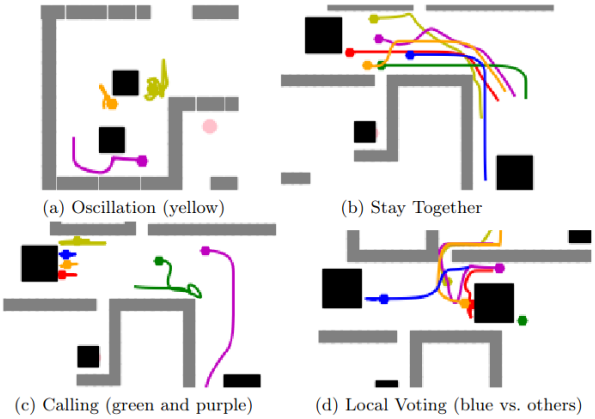


Fig. 2: Emergent behaviours in the non-chat condition

an online multiplayer game where each player controls an avatar and the goal is to move boxes to target positions. Some of the boxes require the joint action of multiple players to be moved, thus requiring players' coordination. We allow for three types of communication within the game: a global chat among all players, a local chat among players within a certain distance from each other and no chat. In all conditions, no external communication among players is allowed. The results of our experiment, involving 6 teams in each condition for a total of 108 participants, show that there was no significant difference between the three conditions in team performance (i.e., the time taken to complete the task). Going deeper in each condition, we show few observed emergent behaviours and implicit communication patterns done by the movement of the player when no chat was allowed. In the global condition, a significant positive correlation is found between the total number of messages and the time taken to complete the task, suggesting that chatting is not necessarily helpful towards coordination. Following a similar trend, the 3 best performing teams in the Local condition were also the ones with the lowest number of exchanged messages, and the lowest chatting frequency. Further observation of the game replays showed the emergence of two distinct triggers for initiating communication: either to agree on an action before taking it, or in response to a conflict/difficulty. A similar qualitative analysis of the players' behaviour in the No-Chat condition revealed the emergence of signalling and coordination mechanisms, based on the avatars' movements and for agreeing on an action.

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