

# Triadic interaction in emergence of communication

Kristína Rebrová, Ľudovít Malinovský, ...

## 1 Introduction

## 2 Communication games

The concept of *language games* has been introduced by Steels (2003) in the field of cognitive robotics. In his methodology robots that perceive and categorise objects in a microworld establish a communication system (protolanguage) in the process of negotiation of shared meaning. Steels applied this methodology also to generations of agents in an evolutionary multi-agent simulation experimentally accounting for universalia in colour naming. (Steels, 2003)

Despite the fact that human communication in most cases includes well established communication means, mostly language, understanding the intentions communicated is essentially a nonlinguistic process exploiting the generation of our own intentions (De Ruiter et al., 2007). To study how communication and its forms might have emerged in a laboratory the means of communication between the subjects of the experiment has to be limited in some way.

### 2.1 Communication game with unconventional medium

First communication game with unconventional communication medium was designed by Galantucci (2005). It was a video game in which two players located in separate rooms share one virtual environment and move their avatars in it. This virtual space comprises four rooms arranged in a square with doors between adjacent rooms. Each room is labelled with a symbol visible to the players only when they visit the room. Also the players are visible to each other only if they occupy the same room.

The goal of the game is for the players to get into the same room only with one move between the rooms. In other words, the players need to let each other know in which room they are and to which they should go to meet.



First rounds, naturally, were lost, but between round players were allowed to freely "walk" around the environment, so they were able to familiarise themselves with the whole map (room names and positions).



Most interesting aspect of this research was the use of specifically designed unconventional communication medium depicted in Fig. 1, namely a magnetic stylus on a moving digitising pad, which's trace was also quickly fading after being presented to the game partner. Importantly, this medium did not allow the participants to use any conventional alphabet and thus force them to develop a new communication system. Results from experiments proved that these new communication systems emerged rapidly and developed parsimoniously; their signs originated from different mappings, yet were perceptually distinct, easy to produce, and tolerant to variations thus reflecting qualities of natural languages.

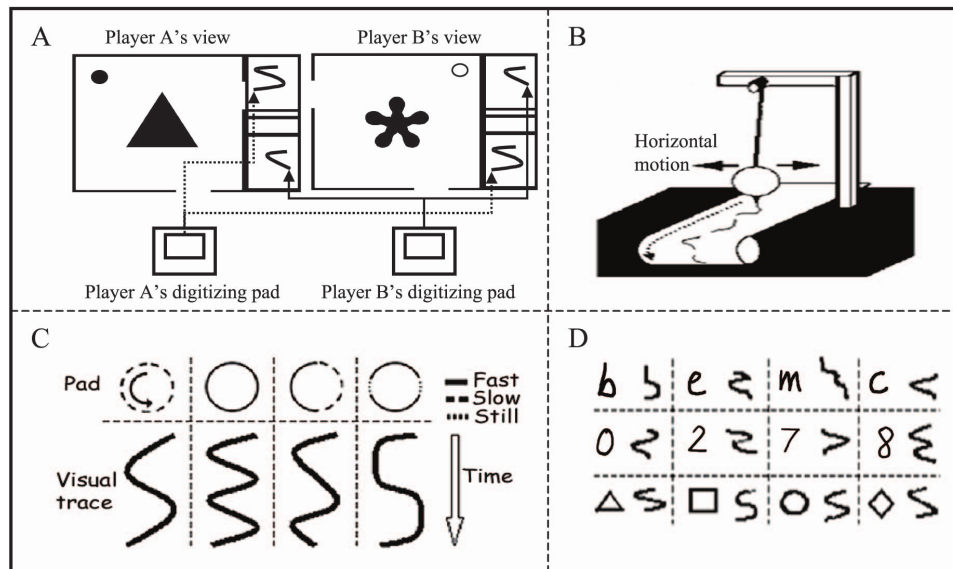


Figure 1: Schematic depiction of the communication medium of Galantucci (2005)

## 2.2 Tacit communication game



First fully embodied communication game was designed by De Ruiter et al. (2007). Similarly to the previous game players located in separate rooms controlled avatars in a shared virtual environment, concretely a 3x3 grid of fields the avatar could occupy. In this game, players are first assigned

specific roles of the sender (**S**) and the receiver (**R**). The first turn belongs to **S**, who sees the goal configuration of the two **player's** avatars and in a limited amount of time has to communicate this setup to **R**. The only means of doing so is the actual movement of the avatar (on four directions) in the virtual environment which is fully observable to both players. After **sender** finishes his turn, the receiver's turn starts (also time limited) in which **R** has to assume the goal position, but also is allowed to embodyly communicate with the sender. One round of this game is illustrated in Fig. 2.

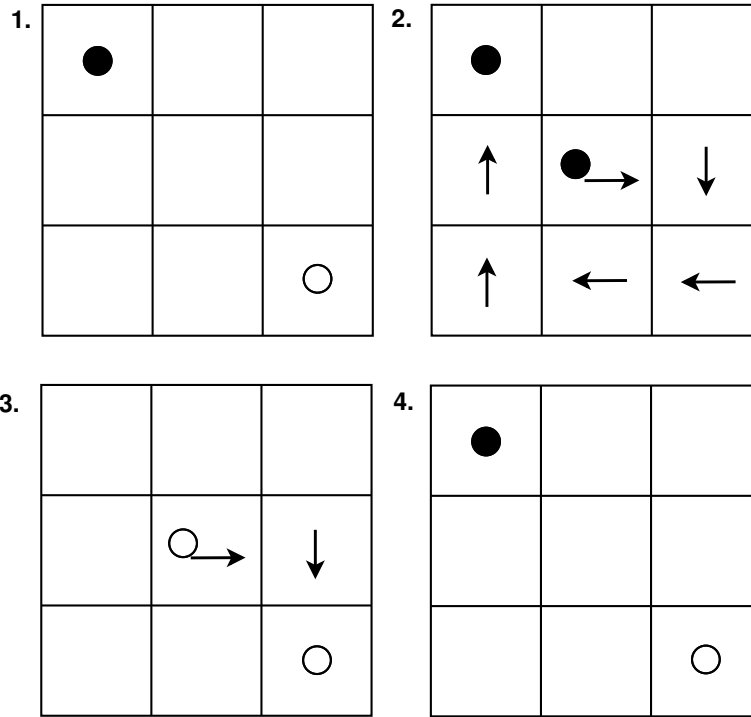


Figure 2: Schematic depiction of the tacit communication game (TCG) - four phases: 1. sender sees the goal configuration; 2. sender's move; 3. receiver's move; 4. final configuration – match with the goal.

After each round both players get the information about its success (i.e. if their final configuration matches the goal configuration). The main motivation for the players is to play as many successful games as possible. Also in this case the first games are expected to fail while the players learn how to communicate to achieve their shared goal. De Ruiter et al. (2010) report that 83% pairs of players of this game were able to establish a successful

communication form. An example of a simple communication sequence was that before assuming his goal position, **S** moved to the desired position of **R** and remained there for some time. Interestingly, **S** used the same set of possible actions for communicating the goal position to **R** as to assume his goal position, so the receiver has to somehow realise when **S** was signalling and when assuming the goal position.

### 2.3 Embodied communication game

To study the nature of human communicative behaviour Scott-Phillips et al. (2009) have developed the so called *embodied communication game*. This game is quite similar to the TCG. It involves two players allowed the same four movements, but it has just four rooms to move about. A significant difference between TCG and ECG is that in ECG each player has slightly different game plan, namely the rooms in the same positions are assigned different colours. Similarly to Galantucci's game, players in ECG do not have predefined roles and can move about simultaneously, not in turns as in TCG.

Figure ?? illustrates one round of ECG. Each player sees different room colours, which are not exclusive to one room, there can be two rooms of the same colour. The aim of the players is to both end up in a room (rooms) of the same colour. After each round, they are shown the colours of both rooms and receive information about success or failure. Similarly to TCG, players are motivated to achieve the highest cumulative game score.

Despite that overall success of players in ECG was lower, all pairs that were successful have established their own communication form. Quite interestingly, the complexity of signals transmitted between players has been gradually increasing during the game, which is in accordance with results of language games with artificial agents (Steels and Belpaeme, 2005). In accordance with the cognitive economy principle of categorisation (Rosch, 1999), players have been consistently using simpler and perceptually distinct codes to communicate their intentions.

## 3 Triadic tacit communication game

As suggested by Malinovský (2014), addition of a third adversary party to dyadic communication presents a pressure on the cooperating couple to disguise their communication intention thus creating a red queen effect resulting in more complex behavior and in emergence of a subtle communication code. To account for this hypothesis in a laboratory experiment with human

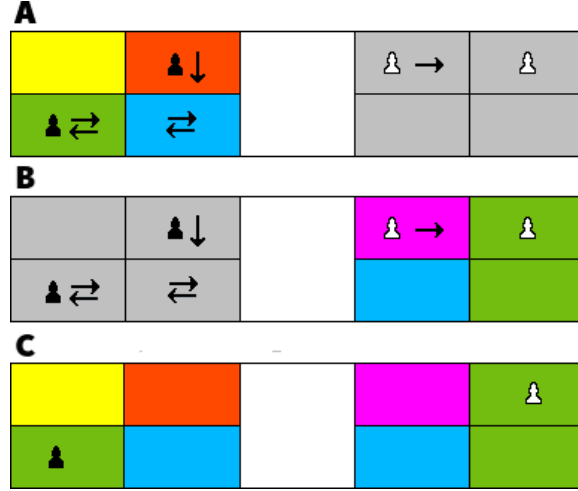


Figure 3: Schematic depiction of the embodied communication game (ECG). A) game as seen by the black player; B) game as seen by the white player; C) final mutual action and .

subjects we propose a novel communication game as an extension of tacit communication game.

### 3.1 Introducing the third player

As the basis for our game we have chosen the TCG due to its high success suggesting that it is easily tractable by the players and also due to its precise structure allowing us to more easily introduce the third party. We call our game the triadic tacit communication game (TTCG). In TTCG there are three roles of players - the sender (**S**), the receiver (**R**), playing in mostly the same way as in the original TCG, and the eavesdropper (**E**), who's main goal is to discover the communication intention of **S** and **R** and assume the same final position as the receiver. TTCG uses the same 3x3 game plan as TCG and players also take time-limited turns to communicate and achieve the given goal position.

Triadic communication as minimal case of broadcast. Also applies to more parties if they are also distributed to two "camps" of receivers and adversaries. TTCG as a task from/for cryptography - information broadcast is unprotected therefore needs to be encoded.

To avoid a situation in which the novel communication will not emerge due to constant interference of the adversary player, and in accordance with

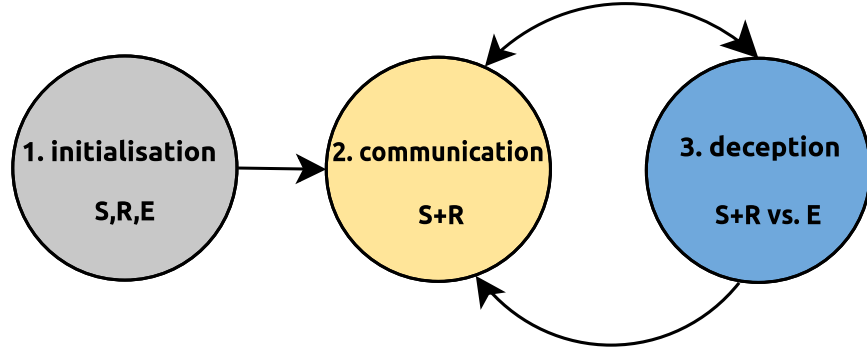


Figure 4: Fázys hry. Po inicializácii prechádza hra do fázy komunikácie, kde hrajú len **S** a **R**. Z tejto môže hra prejsť do fázy zavádzania kedy hrajú všetci traja hráči a naspäť.

cryptography practice in which new secret codes are first designed in a closed environment together with their respective meanings, we have enhanced the original model with so called game modes. Most importantly we distinguish between a **modes** based on the presence of the third player.

### 3.2 Course of the game

The addition of the third player required us to slightly change game course and dynamics. We introduce three game phases depicted in Fig. 4. First, the game is initialised and player are assigned roles. Next, sender and receiver enter a first game mode without the presence of eavesdropper, we call this the *communication phase*. In this phase of the game **player** do not gain any points, so they are motivated to move to the next phase. The phase transition must be unanimously decided by both players. To prevent the players from spending too much time in the first communication phase a time limit is given after reaching which players are immediately moved to the *deception phase*.

As mentioned above, the *deception phase* involves all three players. Here **S** and **R** aim to successfully assume the goal configuration which they are rewarded for and **E** aims at assuming the final configuration of **R**. Players also receive an information on **E** breaking their code which does not come regularly in every round, but is computed from **E** behaviour. **S** and **R** can at any time decide to move back to the *communication phase*, especially when they receive an information that their communication code has been broken by **E**.

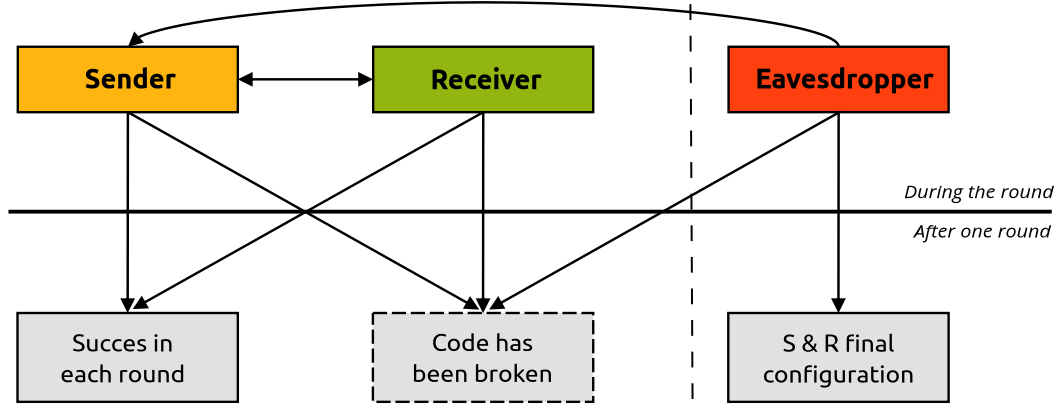


Figure 5: Graf vzájomnej viditeľnosti jednotlivých hráčov. Šípky naznačujú vzájomnú viditeľnosť. v spodnej časti znázorňujeme spätnú väzbu pre hráčov po skončení kola.

### 3.3 Visibility of the players and feedback information



A scheme of what are the players allowed to see is schematically depicted in Fig. 5 together with the information about the game they receive during playing. Apart from his own movement, the sender sees also the movement of the receiver and the final configuration. Both receiver and eavesdropper see the movements of the sender, but not each others. Additionally, the eavesdropper also sees the final configuration of **S** and **R**.



At any time during the *deception phase* all three players can receive a message that their code has been broken. This is the only information **S** and **R** have about the eavesdropper, since they do not see his movements and it also indicates success to the eavesdropper. To account for discoveries based purely on chance we introduce a new parameter to the game based on which the eavesdropper success in discovering **S** and **R** intentions is evaluated.

### 3.4 Code breaking detection and game parameters



The initial mechanism for preventing the eavesdropper to win just by guessing is that only a sequence of successfully assumed goal positions is considered as breaking the code, we call this parameter the *code breaking threshold* (CBT). For initial game design we propose to use  $CBT = 5$ . Other game parameters are mostly time-related. To contrast our game with the original TCG Table 1 displays also values from TCG taken from (De Ruiter et al., 2010). We generally assume that the process of establishing a functional com-

munication code will repeat itself along with the eavesdropper’s discoveries, therefore we decided to allocate significantly more time for the whole game. On the other hand, we also did not want the game to take too long time. The time pressure is expected to urge the players not to remain too long in the unrewarded, but safe communication phase, but to engage in testing their codes in the hostile environments. In general we expect the players **S** and **R** to compete more against other **S-R** teams and eavesdroppers against other eavesdroppers.



Parameter	TCG	TTCG
whole game	40 min	80 min
first communication phase	—	20 min
max turn of <b>S</b>	5s	60s
max turn of <b>R</b> & <b>E</b>	5s	10s

Table 1: Parameters of classic TCG established by De Ruiter et al. (2010) and our TTCG.

### 3.5 Game points and player motivation

The main motivation of the players is to score as many points as they can. In original TCG experiment De Ruiter et al. (2007) rewarded their subjects financially based on their game success. In our design we try to implement similar competitive principle, although we cannot rely on any funding to pay our subjects. Our aim is to have teams of senders and receivers compete with other such teams as well as eavesdroppers against eavesdroppers playing in parallel rather than only current **S&R** against **E**. One reason of such setup is that different game roles gain points at different paces and it might not be trivial to compare game performance of such different roles. On the other hand, game points earned by **S&R** and **E** are by design mutually dependent, so the success of **E** influences the score of **S&R**.



As mentioned above, game points of the players are earned only during the *deception phase*. The sender and receiver receive their points as a team in this way:

- plus 10 points for assuming a successful final configuration;
- minus 100 points every time their code is broken.

In a similar fashion the eavesdropper receives points in this way:

- plus 5 points for assuming a successful final configuration of the **R**;



- plus 50 points every time it has been indicated **he** has broken the code.

To separate two classes of players, teams of **S&R** do not see points of **E** and vice versa. On the other hand, during the whole game they see the points of the **competition** teams on a general score board. We assume to gain sufficient **competition approximately** 5 triads of players should be playing at once and competing against each other.

### 3.6 Game software and user interface

For our purposes we have developed a specific software in ... **blabla**.

The graphical user interface for the game software is schematically depicted in Figures ??, ??, and ??. The GUI inspired by original TCG reflects our amendments to the game including the two phases players can switch between and the space to notify the players about their code being broken.

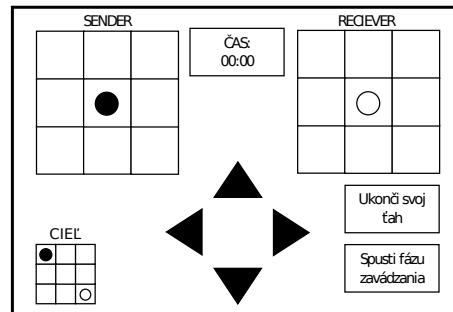


Figure 6: Náčrt grafického prostredia pre sendera

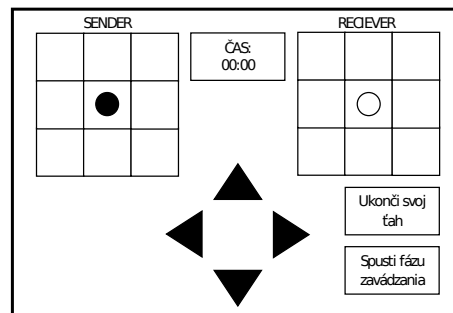


Figure 7: Náčrt grafického prostredia pre receivera

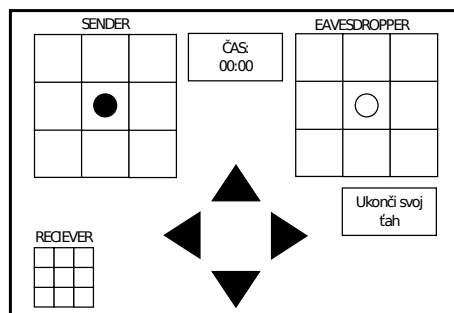


Figure 8: Náčrt grafického prostredia pre eavesdroppera

## References

- De Ruiter, J. P., M. Noordzij, S. Newman-Norlund, P. Hagoort, and I. Toni (2007). On the origin of intentions. *Attention & Performance XXII*, pp. 593–610.
- De Ruiter, J. P., M. L. Noordzij, S. Newman-Norlund, R. Newman-Norlund, P. Hagoort, S. C. Levinson, and I. Toni (2010). Exploring the cognitive infrastructure of communication. *Interaction Studies* 11(1), pp. 51–77.
- Galantucci, B. (2005). An experimental study of the emergence of human communication systems. *Cognitive science* 29(5), pp. 737–767.
- Malinovský, Ľ. (2014). Broadcasting to the enemy: deception as a solution in evolution of language. In *Evolution Of Language: Proceedings Of The 10Th International Conference Evolang 10*, pp. 169–176. Singapore: World Scientific Publishing.
- Rosch, E. (1999). Principles of categorization. *MIT Press, Cambridge, MA*.
- Scott-Phillips, T. C., S. Kirby, and G. R. Ritchie (2009). Signalling signalhood and the emergence of communication. *Cognition* 113(2), pp. 226–233.
- Steels, L. (2003, July). Evolving grounded communication for robots. *Trends in Cognitive Sciences* 7(7), pp. 308–312.
- Steels, L. and T. Belpaeme (2005). Coordinating perceptually grounded categories through language: A case study for colour. *Behavioral and brain sciences* 28(04), pp. 469–489.