COLLEGO: An Interactive Platform for Studying Joint Action During an Ecological Collaboration Task

Alice Chirico[1](✉), Serena Graziosi[2], Francesco Ferrise[2], Alberto Gallace[3], Cedric Mosconi[4], Marie Jasmine Cazzaniga[4], Valentino Zurloni[5,6], Massimiliano Elia[5], Francesco Cerritelli[7,8,9], Fabrizia Mantovani[5,6], Alessandro D'Ausilio[10], Pietro Cipresso[1,11], Giuseppe Riva[1,11], and Andrea Gaggioli[1,11]

[1] Department of Psychology, Università Cattolica del Sacro Cuore, Milan, Italy
{alice.chirco,pietro.cipresso,giuseppe.riva, andrea.gaggioli}@unicatt.it

[2] Department of Mechanical Engineering, Politecnico di Milano, Milan, Italy
{serena.graziosi,francesco.ferrise}@polimi.it

[3] Department of Psychology and Milan Centre for Neuroscience, University of Milano Bicocca, Milan, Italy
alberto.gallacel@unimib.it

[4] Department of Psychology, University of Milano Bicocca, Milan, Italy
{c.mosconi3,m.cazzaniga24}@campus.unimib.it

[5] Department of Human Sciences for Education "Riccardo Massa", University of Milano-Bicocca, Milan, Italy
{valentino.zurloni,fabrizia.mantovani}@unimib.it, m.elia5@campus.unimib.it

[6] CESCOM (Center for Studies in Communication Sciences), University of Milano-Bicocca, Milan, Italy

[7] Clinical-Based Human Research Department, Centre for Osteopathic Medicine Collaboration, Pescara, Italy
francesco.cerritelli@gmail.com

[8] Department of Neuroscience, Imaging and Clinical Sciences, "G. D'Annunzio" University of Chieti-Pescara, Pescara, Italy

[9] ITAB-Institute for Advanced Biomedical Technologies, "G. D'Annunzio" University of Chieti-Pescara, Pescara, Italy

[10] Center of Translational Neurophysiology, IIT - Istituto Italiano di Tecnologia - CTNSC@UniFe, Ferrara, Italy
alessandro.dausilio@iit.it

[11] IRCCS Istituto Auxologico Italiano, Milan, Italy
{p.cipresso,g.riva,a.gaggioli}@auxologico.it

Abstract. We describe the implementation and preliminary validation of an interactive platform – COLLEGO – to investigate joint action in a goal-oriented collaborative task. The platform records the interaction sequence of two partners alternating their leader/follower role. Two sensitized wooden surfaces are placed in front of each participant, who can use 6 cubes to build the tower. Any time a cube is picked/released, time stamp (ms) and position of selected objects are

© ICST Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2018

N. Oliver et al. (Eds.): MindCare 2016/Fabulous 2016/IIoT 2015, LNICST 207, pp. 67–72, 2018.
https://doi.org/10.1007/978-3-319-74935-8_9

recorded. A case study showing how data are collected and analyzed to study dyad performance during the task is described. Finally, potential applications of the proposed solution are discussed.

Keywords: Human-human interaction · Joint action · Synchronization Performance · Time-series analysis · Sensors

1 Introduction

Humans are social animals and as such, they are able to work together co-operatively in order accomplish a shared goal [1]. This is a crucial ability to survive and it is regarded as "joint-action", more widely defined as "*any form of social interaction whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment*" [2].

The experimental study of joint action has been oriented towards the investigation of simplified forms of human interaction, in order to exert experimental control over the parameters affecting behavior and motor executions [3]. Nevertheless, coordinating with another human in everyday life entails a continuous information flow exchange that needs to be experimentally reproduced in ecologically valid ways. On other hand, constraints characterizing an experimental setting do not help pursuing this goal. To address this issue, D'Ausilio et al. introduced and validated [4] the "tower-building task", a goal-directed ecological task to investigate continuous interaction in joint action (see Fig. 1).

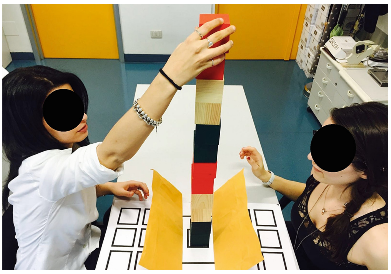

Fig. 1. An example of the "tower-building task" described in [4] to study continuous interaction in joint action.

The task can be used to study motor coordination in relation to several cognitive abilities. It could be also applied for rehabilitation or training purposes. Moreover, it may be used to facilitate the process of planning complex actions that can be grouped in super-ordinate categories as action strategies. Finally, the task is intuitive, minimally invasive, and allows for a continuous interaction among partners.

Given the potentials of this tower-building task, the aim of the present project was to build a sensorized platform to automatically log and record participants' interactions, to investigate joint action in an experimentally-controlled but also ecologically-valid way. The key design requirements were as follows:

- Automatic data collection: the platform had to be able to assess main collaborative interaction parameters automatically (namely, cube position, time reaction for the rising of each cube).
- Continuous recording of building dynamic: platform had to be able to record the sequence of cubes, which were selected by the two partners.
- Modular and flexible design: platform had to be composed of different basic operative modules, which can be eventually integrated with other computational modules/interfaces or other assessment instruments (e.g. physiological sensors).
- Open source hardware and software: platform had to be affordable and easy to build/modify/adapt according to users' needs.

2 Technical Setup

Following the procedure of the tower-building task described in [4], two participants are asked to seat one in front of each other. One participant acts as leader, and the other as follower. The leader has to pick a cube from the platform and to start building the tower. The follower has to imitate the leader, thus take a cube of the same color and put on top of the previous one, until the tower is completed. At the beginning of the experiment each participant is provided with six cubes placed in front of him. The cubes are colored in: green, light and dark brown. Each cube (the length of the edge is 60 mm) is made of wood and weights approximately 160 g. The distance between two adjacent cubes is 40 mm. The main dimensions of the rectangle containing the cubes are 272×172 mm. Both platforms are obtained from a 3 mm thick wooden sheet.

Each platform is equipped with six push buttons, which detect whether the cube has been positioned over the platform, or lifted up. Each button is positioned in a 6 mm square hole under the cube and is plugged to a digital pin of an Arduino UNO board (www.arduino.cc). The initial state of each button is "pushed". Every time a state change of the button is detected (i.e. a cube has been moved away from the platform, or put back on it), Arduino sends a string to a pc through a standard serial communication (baud rate 115200) containing: the timestamp (in ms), the name of the button and the state. These signals are acquired by a software developed in Processing (https://processing.org) which displays, in real-time, the state of the platform to the experimenter. Data are automatically saved in a text file. At the beginning of each experiment all buttons, of the two platforms, are in the "pushed" condition with the cube placed over them. Then, as the experiment continues, the number of pushed buttons diminishes, theoretically, with a step of one button per platform and per task. However, this not always occurs and a post-processing phase is necessary to clean data. To this aim, two more applications have been developed.

One application (developed in Processing) takes as input the text file and creates a movie reproducing what the experimenter has seen during the experiment (see Fig. 2). The other, developed in MATLAB (www.mathworks.com), takes at once all the text files of the trials and clean the data from noise generated during the experiment. Examples of noise are the following: during an experiment the subject can hit a cube while is picking another one, or he can hesitate while lifting one. An algorithm, which keeps the last time the cube has been lifted, has been developed to filter the data. These results are compared with the notes taken by the experimenter, who is asked to keep track of the errors happened during each trial, the failure of the trial and so on. Finally, the post-processing software analyses all the ten trials of a couple and gives as output a unique matrix containing the timestamp and the position of all the cubes that have been lifted from the platform. The timestamp now is computed with respect to the first cube that has been lifted, in order to allow a comparison among all the subjects. This matrix is exported into an Excel sheet for further statistical analysis, to be run in IBM SPSS. Compared to the use of a tracking system, the designed system has two main advantages. First, it is a low-cost, portable and open-source solution representing an optimum trade-off between data accuracy and the complexity of the technology used. This has been possible shifting the focus of the experiment from the kinematic of the subjects' movements to the output/consequences of their actions. This aspect introduces the second advantage which is related to easiness of data elaboration. Indeed, while the tracking system provides, as output, the whole trajectory of the hand, the platform is focused on automatically extrapolating the data of real interest which is the moment when the cube is released.

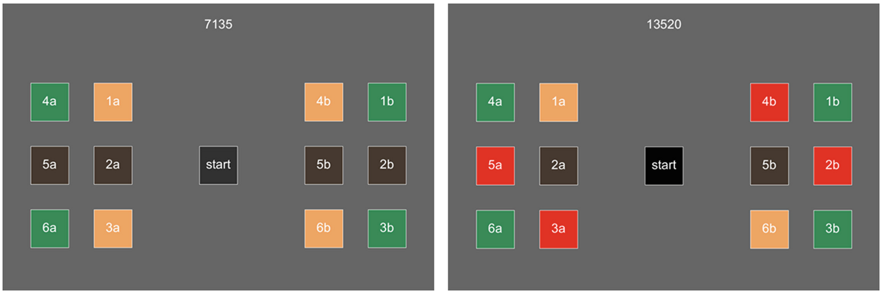

Fig. 2. This application allows the experimenter to replay each trial. The images represent two different frames of a trial (7135 ms and 13520 ms). (Color figure online)

3 Case Study

We tested the platform with 24 female couples (mean age = 22, 33; S.D. = 2, 155) and 24 male couples (mean age = 23, 38; S.D. = 2, 712), all right-handed. The overall 48 couples executed the tower-building task during 10 consecutive trials. They were required to build the tower using only one hand, and positioning a cube at time.

Figure 3 illustrates the variations of dyad performance (time taken to complete trials) of the whole sample across the 10 trials. As expected, linear reduction in execution time across trials may suggest improvement in group performance. These findings suggest that the measures taken by the platform are able to capture learning performance dynamics (Fig. 3).

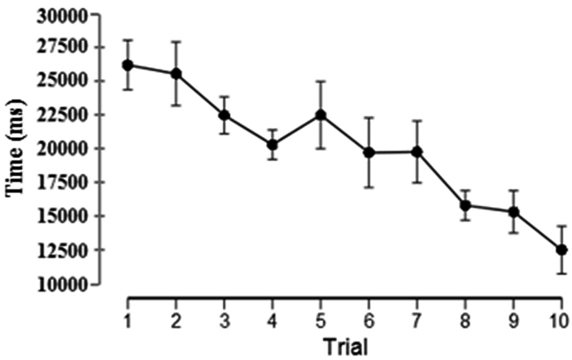

Fig. 3. Descriptive plot for the 48 couples indicating the average duration per each trial execution during the task.

4 Discussion and Conclusion

We described an interactive platform for investigating joint action in an ecologically-valid way. The task does not require any training, is short enough to maintain high levels of engagement, and captures performance data with minimally-invasive recording. This goal-oriented, game-like scenario is based on open source hardware and software components, in order to ensure easy reproducibility and low-cost setup. Findings of the pilot validation study showed that the platform is able to accurately and reliably measure performance of interacting participants. This suggests the potential usefulness of the proposed solution for joint action research. In particular, the engaging and motivating characteristics of the tower-building task could be exploited to study motor coordination in relation to subjective dimensions of partners' collaborative experience, such as the experience of "flow" [5] and social presence (i.e. feelings of mental connectedness [6, 7]. Finally, a more speculative application of this tool might be any doctor-patient relationship, since there is some evidence regarding the potential relevance of movement synchronization in psychotherapy [8].

References

1. Visco-Comandini, F., Ferrari-Toniolo, S., Satta, E., Papazachariadis, O., Gupta, R., Nalbant, L.E., Battaglia-Mayer, A.: Do non-human primates cooperate? Evidences of motor coordination during a joint action task in macaque monkeys. Cereb. Cortex **70**, 115–127 (2015)
2. Sebanz, N., Bekkering, H., Knoblich, G.: Joint action: bodies and minds moving together. Trends. Cogn. Sci. **10**(2), 70–76 (2006)
3. D'Ausilio, A., Novembre, G., Fadiga, L., Keller, P.E.: What can music tell us about social interaction? Trends Cogn. Sci. **19**(3), 111–114 (2015)

4. D'Ausilio, A., Badino, L., Cipresso, P., Chirico, A., Ferrari, E., Riva, G., Gaggioli, A.: Automatic imitation of the arm kinematic profile in interacting partners. Cogn. Process. **16** (Supp 1), 197–201 (2015)
5. Csikszentmihalyi, M.: Beyond Boredom and Anxiety. Jossey-Bass, San Francisco (2000)
6. Biocca, F., Harms, C.: Guide to the Networked Minds Social Presence Inventory v. 1.2: Measures of co-presence, social presence, subjective symmetry, and intersubjective symmetry. Michigan State University, East Lansing (2003)
7. Harms, C., Biocca, F.: Internal consistency and reliability of the networked minds social presence measure. In: Rey, A. (ed.) Seventh Annual International Workshop, Presence (2004)
8. Ramseyer, F., Tschacher, W.: Movement coordination in psychotherapy: synchrony of hand movements is associated with session outcome. A single-case study. Nonlinear Dyn. Psychol. Life Sci. **20**(2), 145–166 (2016)