How social cues improve the perceived affordance of another agent ?

Hugo Romat, Mary-Anne Williams, Xun Wang, Benjamin Johnston

***Abstract* - This paper investigates the problem of perceived affordance of a robot by humans during human-robot collaboration. We use a `pick and place' experiment to study collaborative activities between a human and a robot. The results show that even if participants had good understanding of the maximum reachability of the robot, they take considerable amount of time to assist the robot when a target object is out of reach for the robot. We implemented a number of social cues in the experiment, analysed their effects in order to understand what roles they could play in assisting human-robot collaborations. The experimental results showed that when the robot uses head movements, two hands or a gesture to indicate non-reachability, people react more quickly to assist the robot.**

I. INTRODUCTION

Affordance relates to qualities, properties and/or capabilities of an agent/object that define its possible uses, or make clear how it can or should be used. More formally, it is "an acquired relation between a behaviour of an agent and an entity in the environment such that the application of the behaviour on the entity generates a certain effect" [6]. E.g. a robot arm might afford grasping a cup, or lifting a 7kg weight.

Perceiving affordances of another agent provides information relative to the constraints of the environment, on possible interactions and collaborative actions [1]. For example, perceiving that a robot's arm can only lift 7kgs allows a human partner to ensure the robot is not required to lift an object heavier than 7kgs.

A major problem that arises from joint and/or collaborative actions is to understand how the individual actions of two independent agents can become integrated so to create shared behaviours, and to create a new state of *we-ness* [12].

One of the possible solutions involves the use of the affordance perception by partner agents that could facilitate the embodiment of other agents, and then create a more effective collaboration [2][3]. In the same way as two people work together, when a human works with a robot, he must be able to predict the robot's actions and their consequences in order to achieve cooperation and fluent collaboration [4]. Human-robot collaboration works best when humans obtain continual feedback on relevant aspects of the robot's state.

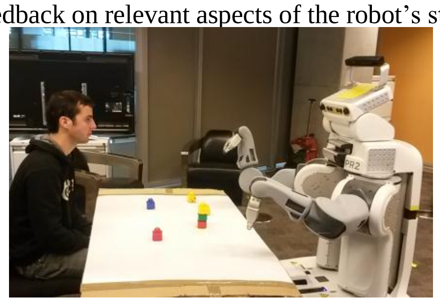

Fig 1: Example of joint action where some objects are out of reach. The human has to understand when the robot is unable to reach the objects.

Existing research work focuses on how to learn affordance from the environment [7], from people, learning affordances such as traversability of an environment [9] or graspability [10], liftability of objects [11], learning affordance from demonstration [5]. This research attempts to understand how an agent will choose to engage in a joint-action depending of the perceived changed in an affordance of another agent, and what kind of cues (gaze, gesture, arm position) could improve the perceived affordance of another agent to create a state of "we-ness". To this end, we designed a simple `pick and place` experiment.

II. EXPERIMENT

In this experiment, we used four Duplo blocks with four different colours. We implemented routines on a PR2 robot such that the robot builds a small tower using blocks with collaboration from a human participant (see Fig 1). The experiment is divided into two parts. The first part was to investigate whether human participants were able to determine precisely the reachable distance of the robot, and the maximum reachable distance of a human. To do this, the participants were asked to draw a boundary region where the robot could reach an object on a table. Then they were asked to build a tower of specific coloured blocks with the robot.

For the second part of the experiment, we designed five different scenarios illustrated in Figure 2: a) is a scenario in which half of the blocks are located on one side of a table, the other half are placed on the other side; b) two blocks are located on the side of the human and one on the side of the robot; c) 3 blocks are placed on the side of the human and one on the side of the robot, and we use a head movement to look to the block that the robot cannot reach; d) we place every Duplo along a straight line; we make the two hands of the robot fully occupied by picking up two blocks in a quick succession. We want to observe how the human engage in the collaborative action. And for the final scenario e), robot executes a 'unable to reach' gesture to indicate it cannot reach a Duplo block.

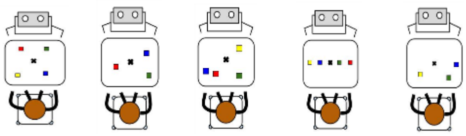

Figure 2: (a) (b) (c) (d) (e)

We recorded the time that the participant took to make an action after the robot finished its action.

We ran the experiment with 10 participants of different gender (3 female; 7 males), different ages (20-40) and professions (1 undergrads, 3 grads, 3 researchers, 3 researchers with non-CS background).

Figure 3: Some different reactions by experiment participants when the robot cannot reach an object.

III. RESULTS

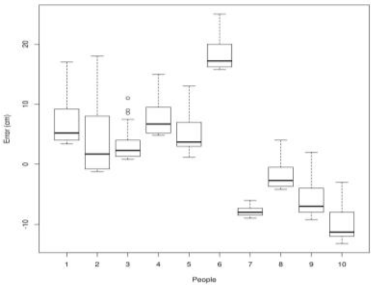

Fig 4: Accuracy to determine the reachability area of the robot

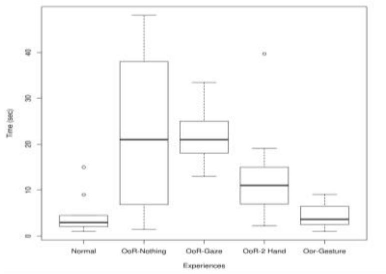

Fig. 5: Time spent by experiment participants when the robot cannot reach an object.

For the experiment Part 1, we evaluated the accuracy of the participants assessment of the robots reachability given by their drawing on the table by comparing the real reachability of the PR2. Fig. 3 showsall the participants were able to accurately to determine to the reachability of the robot, even if they have never seen the PR2 robot previously. Most of the participants achieved an error margin less than 10 cm.

Fig. 4 shows the time that the participants used in the experiment Part 2 under the five scenarios. The time used in the scenario b is the longest with largest variances. The other scenarios (c,d,e) have the same range of time (~10 sec).

IV. CONCLUSION & DISCUSSION

For the experiment Part 1,in the first scenario (a), when all the objects are placed correctly on the table (2 Duplos each), the time the participants took to engage in the joint action, is relatively small (~5 sec). As we predicted, this is the shortest time relative to other experiment (b,c,d,e). Moreover, participants easily observed when the robot was unable to reach an object. However, when the robot did not offer a cue, the human took a very long time to understand what is happening, and to participate in the joint action.

It is surprising that participants with a good understanding of the maximum reachability of the robot, why they did not undertake the action to help the robot when the object is out of reach for PR2.There are several explanations for this behaviour: since the participant is unfamiliar with the robot they cannot predict what the robot will do. This may be due to the pressure of the experiment, where the participant does not want to make any "mistakes". But we believe, as Norman [4], that the human needs continual feedback about the state of the robot, and this kind of behaviour is due to the lack of feedback, the lack of social cues.

Part 2 of the experiment was designed to evaluate if the implementation of simple social cues would help participants to understand this change of affordance, and to react more quickly during the joint action. When we add the head movement that points to the object that the robot could not reach, the response time decrease significantly. The variation of response time is halved compared to the scenario **b**. The use of two hands (scenario **d**) is better understood. People, wait around 10 sec before they engage in the action. Using two hands shows that the robot couldn't carry more objects and gives a valuable clue to the human participants.

The most significant reduction in response time occurred when the robot used a special gesture that indicated the unreachability. People understood what is happening quickly and waited less than eight seconds to engage in the action. Clearly, the use of this gesture conveys important information about the affordance of the robot.

We could utilise voice cues, e.g. "could you pass me the red object?", in the experiment., but in speech is not always possible and it slows down the collaborative process because each partner must wait for verbal instructions, It is our intention to make the robot physical behaviours more similar and natural to a human working with a human in a collaborative setting and not simply following the instructions from the robot [10].

In this paper, we have identified the most important, and most useful cues in a collaborative action to indicate an unreachable object. And we demonstrated that a robot can interact with objects and humans using simple social cues without the voice commands. Moreover, we have also demonstrated that using social cues a human can actively participate in a joint action with a robot, and not as passive agent following instructions.

REFERENCES

[1] Stoffregen, T., Gorday, K., Sheng, Y., & Flynn, S. (1999). Perceiving affordances for another person's actions. Journal of Experimental Psychology: Human Perception and Performance, 25, 120-136.

[2] Hirose, N. (2002). An ecological approach to embodiment and cognition. Cognitive Systems Research, 3.

[3] Tehran J. Davis (2009), Perceiving Affordances for Joint Action

[4] Norman, D. A. (1990). The 'problem' with automation: inappropriate feedback and interaction, not 'over-automation'. Philosophical Transactions of the Royal Society B: Bio Sc, 327(1241), 585-593.

[5] Emre Ugur, Yukie Nagai, Erol Sahin, and Erhan Oztop (2015), Staged Development of Robot Skills: Behavior Formation, Affordance Learning and Imitation with Motionese

[6] Sahin, E., Cakmak, M., Dogar, M., Ugur, E., & Ucoluk, G.(2007). To afford or not to afford: A new formalization of affordances toward affordance-based robot control.

[7] V. Tikhanoff, U. Pattacini,, L. Natale,, G. Metta (2013) Exploring affordances and tool use on the iCub.

[8] Kadir Firat Uyanik, Yigit Caliska, Asil Kaan Bozcuoglu, Onur Yuruten, Sinan Kalkan, Erol Sahin (2014), Learning Social Affordances and Using Them for Planning.

[9] Ugur, E., & S¸ahin, E. (2010). Traversability: A case study for learning and perceiving affordances in robots.

[10] Ugur, E., S¸ahin, E., & Oztop, E. (2009). Affordance learning from range data for multi-step planning.

[11] Dag, N., Atil, I., Kalkan, S., & Sahin, E. (2010). Learning affordances for categorizing objects and their properties

[12] Elisabeth Pacherie (2012), The Phenomenology of Joint Action: Self-Agency vs. Joint-Agency,

[13] Richardson, M., Marsh, K., & Baron, R. (2007). Judging and actualizing intrapersonal and interpersonal affordances. Journal of experimental psychology: Human Perception and Performance