Evaluating the Influence of Automatic Attentional Mechanisms in Human-Robot Interaction

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ABSTRACT

The human ability of unconsciously attending to social signals, together with other even more primitive automatic attentional processes, has been argued in the literature to play an important part in social interaction. In this paper, we will argue that the evaluation of the influence of these unconscious perceptual processes in social interaction with robots has been addressed in previous research in many cases in an *ad hoc* fashion, while, on the contrary, it should be tackled systematically, bridging more conventional measures from robotics with criteria stemming from ideas used in human studies in psychology, neuroscience and social sciences. We will start by establishing an experimental canvas that will limit complexity to a sustainable level, while still fostering adaptive behaviour and variability in interaction. We will then present a brief assessment of the criteria used in the HRI literature to study this particular type of experiments in order to evaluate success, followed by a suggestion of adaptation of other criteria used in human studies, which has only been sporadically and non-systematically performed in HRI research – in most cases, more as expression of future intents. We will conclude by proposing a methodology for this evaluation, to be applied in the project "Coordinated Attention for Social Interaction with Robots" sponsored by the Portuguese Foundation for Science and Technology (FCT).

Categories and Subject Descriptors

A.m [**Miscellaneous**]: Human-Robot Interaction—*Social Robots*

1. INTRODUCTION

When interacting in socially-relevant applications, robots are expected to engage with humans while displaying attentional behaviours that resemble those of their interlocutors; as a matter of fact, they are supposed to be able to assess intentionality and to be, themselves, intentional agents. Humans assess and exhibit intentionality using processes that are deeply rooted within low-level automatic multisensory attention-related mechanisms of the brain; therefore, for robots to engage with humans properly, they should also be equipped with similar mechanisms [3]. In fact, the capacity to attend to social signals seems to be the backdrop to human social interaction. For instance, in toddlers diagnosed as suffering from an autism spectrum disorder, there is a correlation between the attention deficit and their social interaction skills [2].

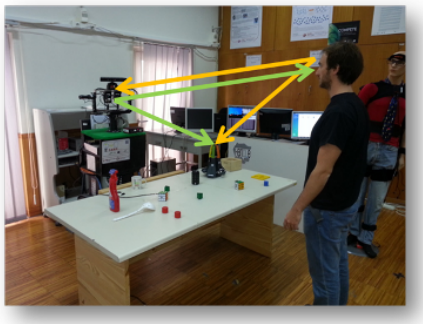

Figure 1: Joint attention as a reference in human-robot interaction research.

We argue that the potential of an *emergent property* of more complex skills from basic building blocks, irrespectively of if these skills are learnt or preprogrammed (as an example of position papers that agree with this point of view, see, for example, [1]). *However, how can the influence of automatic attentional mechanisms actually be measured?*

2. CURRENT METHODOLOGY IN HRI

When two interlocutors look at each other (i.e. they become the focus of attention of one another), we have what is called a *dyadic agent-agent relation*. However, when one of the agents changes his/her/its focus of attention (FOA) intentionally to a third entity, and the second agent follows by *acknowledging* this intention and redirecting his own FOA to that same third entity, we are now in the presence of a *triadic relation*. This intentional attention coordination together with mutual awareness is called *joint or shared attention* – see Fig. 1. In the human developmental timeline,

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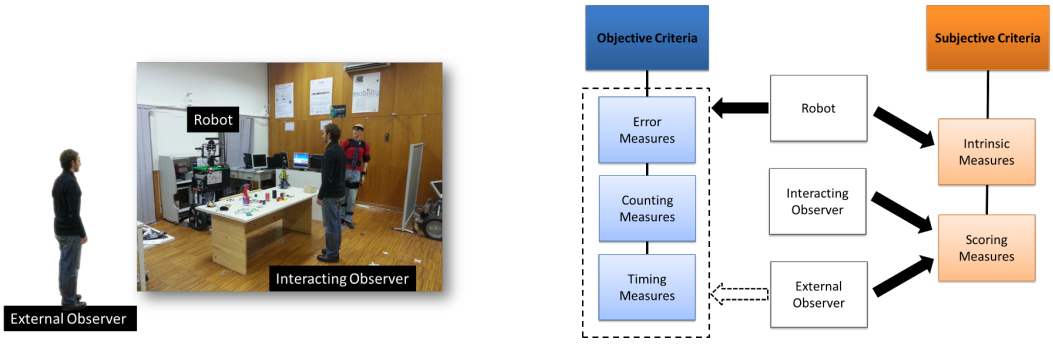

Figure 2: Evaluation criteria definition. Objective criteria consist of quantitative measures taken from recording and analysing robot behaviour, either in an automatized fashion or by an external observer. Subjective criteria primarily result from the standardization of subjective evaluations of the interplay by the interacting observer and by several external observers into scoring scales, following typical guidelines from psychology and neuroscience – intersubject variability due to subjectiveness is then asymptotically levelled out by resorting to a statistics of the complete set of scores. Further subjective measures may also be obtained by duly acknowledging the robot's role as a participating agent, by analysing the evolution of the robot's internal drives, emotions and self-evaluation, if modelled.

this is the first fundamental skill for social interaction relating to attention [6]. This type of social interaction, due to its simplicity and also the considerable body of research work already undertaken in robotics (see for example [4]), is the perfect specific backdrop for experiments to evaluate the influence of automatic attentional mechanisms in HRI.

The most common objective criterion for measuring success in joint attention in robotics seems to be the *detection success rate measure*, applied in experiments where the robot's focus of attention is matched to its interlocutor's, by comparing the robotic observer's expectation to the other's deictic pointing or gazing targets. In some cases, the temporal or trial-by-trial evolution of this success rate is measured. Other examples of objective criteria would be *time-to-error detection* and *length of interaction by time or number of utterances*, human reaction time in response to joint attention (also called "social delay"), and evolution of robot reaction time in response to joint attention. *Time-to-learning convergence* is also important when learning is used. Another interesting (albeit controversial) quantitative measure of joint attention success is obtained by analysing the evolution of the robot's internal drives, emotions and self-evaluation. A detailed survey of the use of these criteria is presented in [3].

In addition to objective criteria, some researchers have resorted to presenting questionnaires to human participants in the experiments, partially relying on their subjective assessment of success – see, for example, [5].

Although some efforts already have been made to define an integrated set of both objective and subjective criteria for evaluation (e.g. [5]), we feel that there is a current need for a focussed and systematic approach to this issue.

3. DISCUSSION

We argue that the evaluation of success in HRI experiments, especially in the specific context of assessing the influence of automatic attentional mechanisms, should conform to a systematic approach of including at least the majority of the criteria mentioned above. We therefore present *an integrated framework*, which would also allow adding new measures, as proposed in Fig. 2. We posit that such a framework would make possible a systematic comparison between the performance in HRI using a model based on a full-fledged attentional system and the same interaction using a tailor-made, stripped-down model.

We believe that this approach, besides representing an important contribution to assessing the importance of automatic attentional processes in social interaction with robots, would also be a major step in the direction of providing a way of benchmarking HRI in general.

4. REFERENCES

[1] O. Déniz, M. Hernández, J. Lorenzo, and M. Castrillón. An engineering approach to sociable robots. *Journal of Experimental & Theoretical Artificial Intelligence*, 19(4):285–306, 2007.

[2] M. Elsabbagh, J. Fernandes, S. Jane Webb, G. Dawson, T. Charman, and M. H. Johnson. Disengagement of visual attention in infancy is associated with emerging autism in toddlerhood. *Biological Psychiatry*, 74(3):189–194, 2013.

[3] J. F. Ferreira and J. Dias. Attentional Mechanisms for Socially Interactive Robots – A Survey. *IEEE Transactions on Autonomous Mental Development*, Special Issue on Behavior Understanding and Developmental Robotics:1–18, 2014. in press.

[4] F. Kaplan and V. V. Hafner. The challenges of joint attention. *Interaction Studies*, 7(2):135–169, 2006.

[5] K. S. Lohan, K. J. Rohlfing, K. Pitsch, J. Saunders, H. Lehmann, C. L. Nehaniv, K. Fischer, and B. Wrede. Tutor Spotter: Proposing a Feature Set and Evaluating It in a Robotic System. *International Journal of Social Robotics*, 4(2):131–146, April 2012.

[6] C. Moore and P. J. Dunham, editors. *Joint attention: Its origins and role in development*, volume vii. Lawrence Erlbaum Associates, Inc, Hillsdale, NJ, England, 1995.