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Towards answering the question: are strategic decision-making and joint attention related when playing Hex-game with humans and robots?

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Abstract—Joint attention (JA) is a fundamental skill for human interaction, allowing individuals to focus on things together with others. Through this capacity, humans can share experiences about the world, coordinate thoughts and behaviors, and successfully cooperate with others. In order to adapt to human environments, social robots should be able to demonstrate interaction skills in a way that is understood by humans, making communication more engaging and intuitive. Furthermore, JA is a fundamental component of joint action research in HRI, finding several applications in assistance, educational, service and entertainment, among others. This work is interested in studying social cognitive and motivational processes unfolding in interaction, such as strategic decision-making and engagement. For this, we take into account an interaction scenario consisting in playing Hex-game and study JA by comparing human-human and human-robot game-playing interactions. Thereby, our objectives are structured in two parallel fronts conducted at the University of Lorraine (LORIA lab) and Kyutech. The HRI prototype is under development at LORIA for playing Hex-game with the robot iCub through a touch screen, whereas a human-human pilot study (including behavioral and electro-encephalogram captures) was conducted at Kyutech, including 8 participants who played a total of 6 matches in pairs. From these efforts we hope to understand how JA can influence playing strategies in Hex-game and identify behavioral and brain activity related to social cognition processes.

I. INTRODUCTION

Joint attention (JA) is a fundamental skill for human social cognition, allowing individuals to focus on things together with others. As a multi-dimensional construct, JA involves cognitive skills which constitute forms of social attention at distinct levels of interaction and knowledge sharing [7], which must be considered in HRI. Through this capacity, humans can share experiences about the world, coordinate thoughts and behaviors, and successfully cooperate with others. Reduced JA is associated with deficits in social cognition, which is observed in psychological conditions such as autism spectrum disorders (ASD) [1]. Hence, we are interested in exploring possible ways social robots could help to develop social skills in humans.

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Inspired by 4E cognition [4], we believe that for social robots to leave the lab and adapt to human environments, it is crucial to provide them with forms of behavior regulation which take into account the dynamics of human low-level social processes, such as the capacity of engaging in JA, and the possibility of those processes unfold in direct interaction. Therefore, this work focuses on the research of intuitive forms of human-robot social interaction, characteristic of rudimentary cognitive skills (e.g. gaze tracking, imitation, attentional sharing, working memory), which can influence high level decision-making as an hermeneutic process developing in face-to-face interaction, and can be studied from a dynamical system perspective (e.g. [3], [2]).

Playing Hex-game with iCub

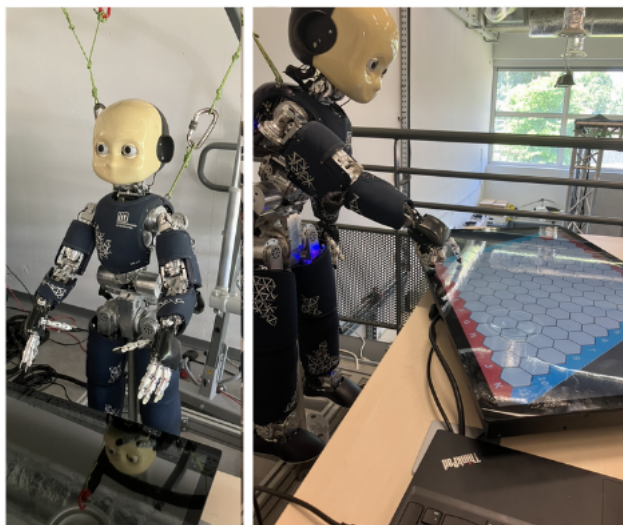


Fig. 1. Hex-game is implemented in a touch screen for playing with the robot iCub. The move gesture of touching the screen is emulated so the board changes the state to reflect the robot's choice.

We are particularly interested in studying in HRI the relation between JA and strategic decision-making, and how engaging in JA could affect the latter. For this, we have chosen playing Hex-game as an interaction activity, since it is a fun game where first-movers in the best case win, and no draws occur. We believe that playing Hex-game with robots could help developing social skills in ASD children (see Fig. 1). Thus, we propose a methodology to evaluate the following hypothesis:

- (i) Shorter decision-making time is obtained by engaging

- in JA with a humanoid robot (e.g. iCub) from gaze cues.
- (ii) The game situation and embodiment can help training JA skills in ASD persons.

Next, the methodology under development for evaluating these hypotheses through the study of human-human and human-robot Hex-game playing is described.

II. METHODOLOGY

A. Playing with robots

A face-to-face interaction scenario was designed (see Fig. 1, consisting of playing Hex-game with iCub through a touch screen. The robot iCub is programmed to produce behavior cues to inform its next move intention and then acting by emulating touching the screen. Participants will play the game in two conditions: with and without the robot (i.e. with an AI algorithm). Participants' behavior will be registered from RGBD cameras, an eye-tracker system Tobii ProGlasses and electro-encephalogram (EEG).

B. Playing with humans

In the human interaction scenario, we focused on the role of JA in strategic game-play dynamics [5]. We conducted a pilot study where 8 participants (4 pairs) played six matches, alternating the starting turn. Matches lasted between 2-3 min, with a one-minute rest (see Figs. 2, 3). Players were instructed to synchronize their moves with a quarter note downbeat of a 80 BPM audible signal.

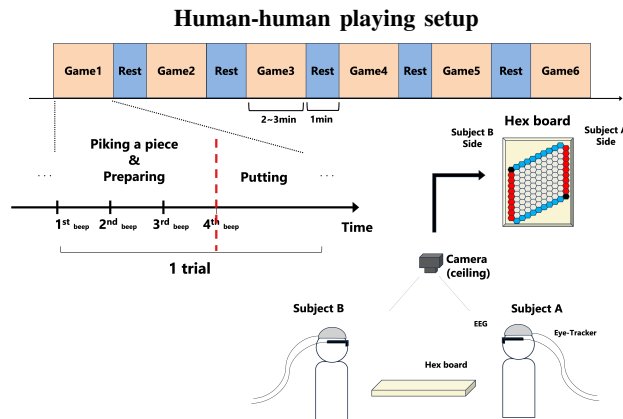


Fig. 2. For handling random motion artifacts on EEG measurements, the game's progression is synchronized to a 80 bpm audible click and subjects are instructed to do a move at a quarter-note downbeat emphasis.

III. RESULTS AND PERSPECTIVES

Concerning the HRI prototype, the software was implemented for playing Hex-game on a touchscreen and a regulation scheme was attempted in open-loop for emulating the move-making gesture with iCub. Results were not satisfactory since the arm is tendon actuated with low precision. Therefore, we plan to control the move gesture in closed-loop by tracking a marker attached to the moving hand.

For human-to-human interactions a dataset was constituted to elucidate how the players' gaze and brainwave patterns

Humans playing Hex-game

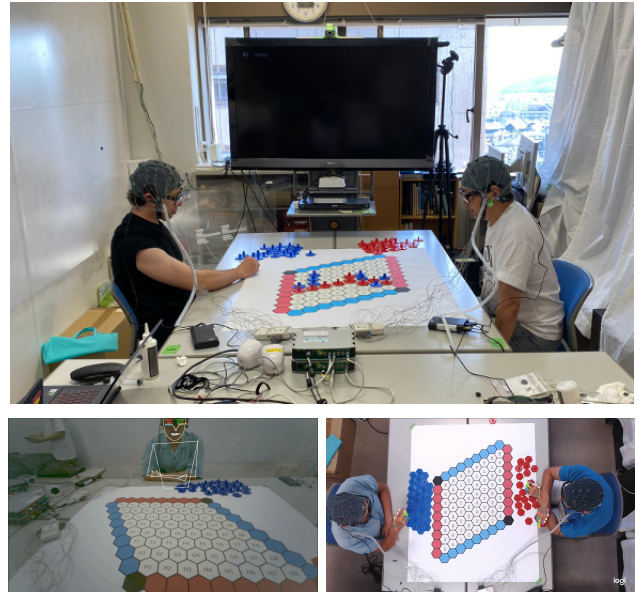


Fig. 3. Measurements included gaze- and EEG-tracing and images from four perspectives: the ceiling, the side, and head-mounted. All data were synchronized in time using trigger signals.

evolve and influence each other throughout game progression and strategic context. To investigate these dynamics, we will classify game states based on movement data, piece positions, and cue timings, followed by complementary analyses to identify the specific changes and interactions occurring within these classified states. We also consider the aspect of artifact removal from multi-resource bio-signals (e.g. [6]) which helps shedding light on the complex relationship between gaze and brain activity, having the potential to enrich our understanding of JA related cognitive processes.

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