Joint Action, Adaptation, and Entrainment in Human-Robot Interaction

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***Abstract*—Research in joint action focuses on the psychological, neurological, and physical mechanisms by which humans collaborate with other agents, and overlaps with several domains related to human-robot interaction. The development of artificial systems that can support or emulate the requisite aspects of joint action could lead to improved human-robot team performance as well as improvements in subjective metrics (e.g., trust). This workshop highlights theoretical and technical considerations about human-robot joint action and real-time adaptation, with a particular focus on socio-motor entrainment, showing how the emulation of psychological mechanisms (e.g., emotion, intention signaling, mirroring) can lead to improved performance. We will invite speakers with backgrounds in robotics, neuroscience and psychology, as well as speakers with a focus in adjacent works, such as in human-robot coordinated dance, alignment, or synchronization. We will call for papers that utilize the theory of joint-action in an interactive human-robot context. We will also call for position papers on the application of the theory of joint action to robotics, with a heavy focus on psychological mechanisms that could potentially be emulated or adapted to a human-robot context. Participants will have the opportunity to brainstorm considerations and techniques that would be applicable to joint action inspired works through breakout sessions with the aim to lead to new and improved collaborations across fields.**

***Index Terms*—joint action, adaptation, entrainment, human-robot interaction**

I. Organizing Committee

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- **Prof. Malte F. Jung (Cornell):** Associate Professor, Department of Information Science, Cornell University

II. Workshop Overview

This workshop intends to highlight techniques and considerations for human and robot joint action, with an additional focus on socio-motor entrainment showing how the emulation of psychological mechanisms can lead to improved performance. The workshop will highlight three themes: joint action, adaptation, and entrainment. These perspectives will be explored from the viewpoints of roboticists, neuropsychologists, and cognitive psychologists. The workshop will also have opportunities for cross collaboration in the form of interactive breakout sessions.

Major Themes

1) **Joint Action** in humans has been studied extensively in psychology to model the fundamental cognitive and behavioral mechanisms enabling interaction, cooperation and coordination in collaborative tasks [1]–[3]. Processes such as joint attention, entrainment, task co-representation, adaptation, and anticipation occur naturally in human-human joint actions [4], while emotion has also been highlighted as a key consideration that enables such joint actions [5]. In robotics, the theory of joint action has been adopted to solve a plethora of problems that arise in human-robot-interaction (HRI) tasks. From examining role assignment policies for human–robot joint motor action, human action and intention detection to shared control, force control, human-robot teaming, and human-robot handovers; the theory of joint action has been shown to be an appropriate model for HRI [4], [6]. In this theme, we seek to showcase latest results and insights from research in human-human and human-robot joint action, from psychologists, neuroscientists and roboticists, in order to bridge the gap between the fields and promote tighter collaboration.
2) **Adaptation:** this extends the discussion in the earlier theme by focusing on adaptation in joint action; a critical component in human-robot interaction for which insights could be invaluable. To effectively collaborate, humans and animals are often adapting and co-adapting to changes in environmental, cognitive, and physical processes. For robots to seamlessly collaborate with humans, such adaptive and co-adaptive behaviors must be the basis of any interaction scenario. Research from the robotics community as well as neuroscience and psychology, have extensively explored mechanisms, organizational principles, and architectures that can express adaptive behaviors in computational, physical, or mathematical models in both biological as well as autonomous artificial systems. In this theme, we seek to explore the current challenges in the cognitive, behavioral and engineering sciences to better understand the role of adaptation in human-robot interactive systems. Topics of interest can include (but not limited to): adaptation in perception and motor control, embodied cognition, learning, neural mechanisms of adaptation and co-adaptation, decision making, mechanical and cognitive adaptation in robotic systems, etc.
3) **Examples of Insights from Joint Action (e.g. Entrainment)**: in this theme, we wish to explore examples of insights from joint action, with entrainment as an example that could lead to improved human robot collaboration. Entrainment is a general term describing temporal coordination of individuals, with experimental evidence suggesting that it is extremely hard to resist [3]. More specifically, entrainment is the process that leads to the synchronization of two collaborating individuals, even "in the absence of a direct mechanical coupling" [7]. This theme is not limited to entrainment, but can include additional examples of insights that lead to improved interaction. It stands to reason that this process could lead to improvements in human-robot coordination, improving objective metrics of human-robot teaming (such as fluency [8]), and potentially improving efficiency of tasks. Much of the work on the subject within the HRI community has been limited to lexical entrainment [9], [10], rhythmic group actions (e.g. dance) [11], or rhythmic, combined actions [12]. However, the scope of entrainment (or the resultant synchronization) could be much larger; applying to more complex tasks, dynamic group behaviors, or abstract rhythmic interactions.

A. Workshop Format

We will invite speakers with backgrounds in both robotics and psychology. We will also invite speakers with a focus in adjacent works, such as in human-robot coordinated dance, alignment, or synchronization.

The workshop will also have an interactive component. Participants will brainstorm considerations and techniques that would be applicable to joint action inspired works that could also lead to new and improved collaborations. We will call for papers that utilize the theory of joint-action in an interactive human-robot context. We will also call for position papers on the application of the theory of joint action to robotics, with a heavy focus on psychological mechanisms that could potentially be emulated or adapted to a human-robot context.

Discussion Topics:

Panel discussion topics and speaker themes:

1) *Roboticists, Neuroscientists, and Psychologists on Joint Action*: what is the ideal robot? What is joint action, and why do we care about it? What are the fundamental processes that underly human-human coordination? How can insights from human-human joint action influence robot design?
2) *Mental representations and sensorimotor information for Joint Action*: What is the appropriate mental model representation for human-robot joint actions? What sensori-

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motor information is necessary for modelling human-robot join actions? How to represent joint action in multi-agent systems with different cognitive and physical capabilities?

3) *Mutual Adaptation and Entrainment: Insights from Joint Action*: we focus on examples of inductive biases that we can leverage from joint action. What aspects of joint action can we coordinate on to emulate (low-hanging fruit etc.)? How do entrainment and human adaptation affect our understanding of human-robot systems? Examples of processes for joint action that we can adopt from humans include: joint attention, entrainment, task co-representation, adaptation, and anticipation, among many others.

B. Tentative Schedule

One full-day workshop rough plan:

09:00-09:10	Opening Remarks
Block 1:	**HRI and Joint Action:**
09:10-10:25	5 speakers, 15 minutes each
10:25-10:45	Panel Discussion
10:45-11:00	Lightning Talks
11:00-11:30	Breakout Session 1
11:30-12:30	*Lunch*
Block 2:	**Mental Models and Sensing:**
12:30-13:45	5 speakers, 15 minutes each
13:45-14:05	Panel Discussion
14:05-14:15	Lightning Talks
14:15-14:45	Breakout Session 2
14:45-15:00	Coffee Break
Block 3:	**Adaptation and Entrainment:**
15:00-16:15	5 speakers, 15 minutes each
16:15-16:45	Panel Discussion
16:45-17:15	Breakout Session 3
17:15-17:30	Closing Remarks

Panel discussions and breakout sessions will be led by expert members of the organizing committee.

C. List of Invited Speakers

- Roboticists / Technologists
  - Guy Hoffman, Malte Jung, Dagmar Sternad, Yanan Li
- Cognitive Neuroscientists / Psychologists
  - Benoit Bardy, Atsushi Takagi, Natalie Sebanz, Cristina Becchio
- Adjacent/Overlapping Works
  - Amy LaViers, Alexandra Battaglia-Mayer, Martin Clayton, Emily Cross

III. Target Audience

The target audience of this workshop are social roboticists, researchers in pHRI (physical Human Robot Interaction) as well as researchers in cognitive psychology working on the theory of joint action.

IV. Approach for Recruiting Participation

We intend to solicit participation primarily through e-mails to relevant communities, with the assistance of our organizing committee. We will also leverage social media to enhance our distribution and encourage participation.

We will call for papers that utilize the theory of joint action in an interactive human-robot context, as well as position papers on the application of the theory of joint action to robotics, with a focus on the pyschological mechanims that could potentially be emulated or adapted to a human-robot context. A detailed call for papers, including projected review and notification dates, is appended to this document.

V. Plan for Workshop Documentation

We intend to write a report based on the results of our breakout session discussions and contributed papers to point out interesting models from joint action, adaptation and insights such as entrainment that will benefit the advancement of human-robot interactive systems. We will target publishing this report at one of the leading robotics journals such as ACM Transactions on Human Robot Interaction, IEEE Transactions on Human-Machine Systems or Foundations and Trends in Robotics. Workshop materials, including recordings of talks (with the approval of the speaker) and accepted submissions will be hosted on the workshop website for public access. Workshop submissions will not be archival.

VI. Call for Papers

We invite 2-4 page extended abstracts on work that utilizes the theory of joint action in an interactive human-robot context, as well as position papers highlighting cognitive processes drawn from the field of joint action for potential use in human-robot collaboration. The primary aim of the workshop is to bring together technologists and cognitive- or neuropsychologists, and as such, previously published work is welcome. Longer format submissions for previously published work are allowed, but please contact the organizers if you are considering this submission option. All accepted submissions will be made available on the workshop website as non-archival reports so that submissions to future conferences and journals will be possible. Selected submissions will be invited to contribute to an archival report that we intend to publish on the topic.

The primary areas of interest include:

- The application of the theory of joint action directly in human robot collaboration
- Models leveraging insights from joint action to better inform human robot collaboration
- Prospective heuristics, insights, or biases that could be leveraged in human-robot collaboration (e.g. entrainment)

The deadline for submission is Jan 31, 2022 at 11:59pm EDT. Late submissions may be accepted for review at the discretion of the organizing committee. Submissions should follow the ACM template.

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