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To cite this version:
Waldez Gomes, Pauline Maurice, Serena Ivaldi. Dyadic Motor Behavior During Co-manipulation: A Study on Humans. 2018. hal-03283057

HAL Id: hal-03283057
https://hal.science/hal-03283057
Preprint submitted on 9 Jul 2021

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Dyadic Motor Behavior During Co-manipulation: A Study on Humans

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Introduction

Human-Robot Collaboration
- Control a robot to act efficiently with a human during a task that requires co-manipulation;
  - Human and robot co-manipulating a shared object
- Good collaboration is not only fast and/or accurate, but it is also legible
- Good collaboration feels natural!

Planning and execution are a responsibility of all agents
- The task requires coordination and synchronization

Is there a Leader, or a Follower?
- So we look into natural motor behavior in human-human dyads!

Goal
- Design a task to investigate how human-human (HH) dyads motor behavior is influenced by different leadership conditions (leader or follower) during an object co-manipulation:
  - Hypothesis 1: Arm stiffness is influenced by leadership conditions;
  - Hypothesis 2: Object's trajectory is influenced by leadership conditions
  - Hypothesis 3: Accuracy of the task execution is influenced by leadership conditions
- Investigate the same task, but with one human executing the task alone.

Methods

Co-manipulation by a Human Dyad

Task
- Collaborative extraction and insertion of a pipe in a tube
- Contact between the pipe and the tube should be avoided

Experiment
- 10 dyads
- 3 randomly assigned behaviors:
  - Participant 1 leader, Participant 2 follower
  - Participant 2 leader, Participant 1 follower
  - No pre-assigned leader behavior
- 5 trials per condition
- Practice trials between conditions

Sensors and Data
- Qualisys optical motion capture: 6 markers on each participant's right arm, 1 marker on the pipe → Arm kinematics → Pipe 3D trajectory
- Wireless EMG DelSYS Trigno on 3 pairs of antagonist muscles: forearm, arm, shoulder → Muscle activation → Index of Co-Contraction (ICC)
- Contact sensors on each tube (Quantitative measurement of accuracy)

Index of Co-Contraction
- The ICC is an indirect measure of the arm stiffness, in here, calculated from a pair of forearm antagonist muscles EMG signals:
  \[ ICC = \min(u_{agonist}, u_{antagonist}) \]

Contact Sensors
- Less contacts when there is no pre-assigned leader (Hypothesis 3)
- No clear difference between conditions in which there is a leader

Results

Trajectory in Co-Manipulation
- Trajectory seems to deviate towards the position of the participant that is the leader (Hypothesis 2)

- When the pipe is closer to the participant, it is harder for the participant to move the hand in different directions (low arm manipulability values are expected)
- Each participant may have its own desired trajectory, that is chosen according to several criteria, including arm manipulability.

Future Work
- Rigorous analysis of the trajectories
- Define manipulability metrics for a dyad, and apply them to all dyads
- Use the stiffness modulation from the human arm to modulate the stiffness of the robot in a human-robot collaboration

Acknowledgements
- This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 731540 (An.Dy)