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

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 antagonistic muscles: forearm, arm, shoulder
- Muscle activation
- Index of Co-Contraction (ICC)
- Contact sensors on each tube (Quantitative measurement of accuracy)

Goal

- 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!

Index of Co-Contraction
- The ICC is an indirect measure of the arm stiffness, calculated from a pair of forearm antagonist muscles EMG signals:

\[
ICC = \min (u_{\text{agonist}}, u_{\text{antagonist}})
\]

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)