Intention Disambiguation:

When does action reveal its underlying intention?

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Some authors have recently characterized an intention as as an agent's goal (or aim) plus a plan of action to which the agent commits as a means of achieving such a goal or aim. Therefore, an intriguing question is: "After the onset of the plan of action leading to the goal, how early will its associated intention be fully revealed?" This is an important question for HRI. In service and assistive robotics, effective and timely monitoring of intentions is paramount. For example, early recognition of intentions might allow the prevention/termination of a potentially dangerous course of action while still operating within the principle of minimal cognitive and physical interference with the subject's activity.

In the experiment reported in this paper, 16 participants (representing a fairly distributed sample of adult volunteers randomly recruited at a public University) were requested to physically reject a cup presented to them. Either the left or the right side of the cup (according to a randomly selected sequence of 10 tries for each participant) was accessible through the corresponding side of a narrow window placed in front of them (Fig.1, left panel). The participants could physically contact the reachable side of the cup and reject the cup by pushing it to the right or to the left with their extended index finger. In other words, the participants had to: (i) establish contact with the cup (the contact area was typically identified by the tangent to the rim that was exposed through the window and parallel to the direction of approach) and (ii) reject the cup by pushing it to the left or to the right, as made possible by the contingent position of the cup behind the narrow window. Crucially, the setup had been carefully designed so that, at the moment of making contact with the cup, the

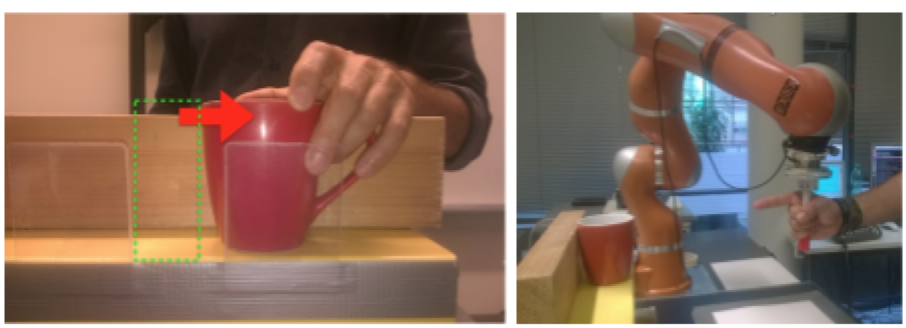

Fig. 1 - left panel: The cup to be rejected is presented to the participant through a narrow window (this picture shows the participant's view). Typically, participants make contact with the point on the cup's rim where the tangent to the rim is parallel to the direction of approach **- right panel:** The participant contacts and pushes the cup by the extended index finger, while holding a handle mounted on a robot for simultaneous pose and F/T measurement.

position of the extended index finger would be approximately the same, independently on the fact that the cup had been presented from the left or from the right side of the tiny window.

In instructing the participants, we carefully avoided the instillation of conflicting behavioral biases. Therefore, we asked the participants to simply reject the cup by pushing it to the side. In particular, by making use of a cover story involving bad coffee, we avoided suggesting behavioral chunking and action compositionality (i.e. we avoided saying things like: “Reach for the window, then push the cup”). Reinforcement was given, inviting the participants to stay focused on the rejection of the cup and on energetically pushing the cup away.

During the experiment, the participants would tightly grab a handle connected to a state of the art robot with their non-dominant hand. Their index finger, maintained in extended position, was used to push the rejected cup (Fig.1, right panel). The robot allowed accurate pose measurement (cartesian and angular position). Information about force/torque applied by the participant to the handle was also recorded, as estimated by the robot and also measured by a force/torque sensor mounted between the handle and the robot’s flange. During the recording, the robotic arm was maintained in gravity compensation, i.e. the robot would smoothly and effortlessly follow the participant’s movement. Therefore, in this simple case and under hard real-time conditions, we could extract a rather complete picture of how biological action is actually deployed during the task. Due to previous participation in a different experiment, all the participants had already experienced moving the robotic arm under gravity compensation.

Our preliminary results show that a simple criterion for early disambiguation of the two families of actions, generally valid across the whole population of participants, cannot be extracted. However, soon after action onset individual stereotyped patterns of behavior begin to emerge and can be easily identified for several participants. The dimension of interest can vary widely across participants. For example, the trajectory for one class of behavior (push right) exhibited by some subjects might tend to take internal paths, while external paths will be followed for the other class (push left). In other cases, the elevation of the movement is the salient element (i.e. behavior that will develop into pushing the cup to the right displayed a characteristic elevation as contrasted to behavior associated to pushing the cup to the left). In some cases, the speed or the latency in the onset of the movement itself expressed significant information.

In conclusion, our results seem to support an important general message for intention recognition in the field of HRI: (i) early disambiguation of intentions is possible. However, (ii) intention recognition needs to be addressed based on individual rather than general stereotypes and (iii) it manifests as (combinations of) multiple different dimensions. Flexible, customizable machine learning methods, based on a rich collection of perceptual information about the subject’s kinematics, constitute a promising approach to the early classification of human intentions in a natural scenario. Future work will focus on the generalization and systematic analysis of these promising results.