

C. Breazeal, D. Bushbaum, J. Gray and B. Blumberg's  
Learning From and About Others:

Towards Using Imitation to Bootstrap the Social Competence of Robots

Infant imitation has been identified as a vital catalyst for social behavior in humans. Its importance lies in imitation's role in the development of a number of social capabilities, the most important of which are social identification ("others are like me") -- achieved through the existence of cross-modal recognition; turn-taking; communicative skills; and the emergence of motor skills. Also, so-called *mirror neurons* quoted herein have been found to provide a possible neurological basis for imitative abilities.

The research presented in this paper follows the path laid out by findings in developmental and cognitive psychology, in particular work done by Meltzoff et al. in human infant imitation. Meltzoff proposes a model called "Active Intermodal Mapping" (AIM) underlying imitative competence, and the authors employ an artificial implementation of AIM to train a robotic creature ("Leonardo") to recognize and faithfully reproduce human facial expressions.

In a nutshell, the experiments described go as follows: Leonardo starts out with a blend space of facial expressions, defined by extreme poses over 3 subfacial regions. In a motor-babbling phase, Leo identifies when he is being imitated using contingency detectors. Whenever such an imitation is identified, a neural network is trained to correlate the facial expression of the human to the current internal representation of Leo's facial pose. Following the training session, Leo imitates the human, by first applying the neural network to create an approximate imitation pose (in motor-space), then identifying the closest extreme pose for each facial subregion, and finally hill-climbing the lower-dimension pose blend space for the optimal pose reflecting the expression assumed by the human trainer.

Breazeal et al. successfully demonstrate the application of psychologically modeled mechanisms not only for faithful imitation of a fixed set of facial expressions but also of a continuous blend space of these expressions, including new combinations of sub-expressions as shown in the case of the eyebrow raising. Many biological concepts were fruitfully converted into the artificial realm, most notably the identification of organ prior to pose, the hillclimbing stage of real infant imitation, the use of caregiver imitation of infant babbling, and finally the detection of contingency.

Other constructs and metaphors borrowed from the world of cognitive psychology, while mentioned in the paper, are not widely employed in the experiments discussed. Turn-

taking is only remotely present in the single-turn two-part algorithm. Mirror neurons and simulation theory are at best implicitly represented in the mental systems of Leonardo. In particular -- while these experiments do show a promising new approach to imitation -- it does not seem immediately apparent how the imitative capabilities displayed can lead the way to a theory of mind and also (and maybe more importantly) what tools and criteria can be used to measure the existence of such a theory of mind.