# Do Robots Ape?

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**Abstract**

Within the context of two sets of robotic experiments we have performed, we examine some representational and algorithmic issues that need to be addressed in order to equip robots with the capacity to imitate. We suggest that some of the difficulties might be eased by placing imitation architectures within a wider social context.

## Introduction

Robot designers are frequently faced with a problem which could be seen as an instance of the Nature vs Nurture debate, commonly found in the natural sciences: while there seems to be a general consensus that tabula rasa algorithms for robot learning are unlikely to be successful, robot designers tend to agree that preimposing their own perceptions on the robot's control structure might prove counterproductive as they strive toward more adaptive robots.

Recently, imitation, which is seen as an important method of learning in the animal kingdom (Whiten and Ham, 1992), has been proposed as a promising method for a compromise between the two approaches. While the robot architecture is designed in order to benefit from other agents' knowledge, this is done "from the inside", i.e. the robot learns about the world based on its own perceptions. Imitation can be used as a guide [shaping process] for the robot during its social development in human and robot societies.

## The issues

Where do we start? We believe that in order for a robot to be able to imitate, the following should be taken into account:

- There are several different levels of imitation, which do not necessary share the same underlying mechanisms. We see at least three levels:

  (A) **Basic imitation** as reproduction of the perceived stimulus, for example, imitation of body movements or speech sounds.

  (B) **Functional imitation**, for example picking-up an object, moving towards a door, making a sound to scare off a predator, etc. Essentially, in this level, its not the exact stimulus that is being imitated but rather the effect that it has.

  (C) **Abstract imitation** or social attunement, i.e. imitation not of the external action but of the presumed internal state of the partner (for example, making a sad face when another one is crying, smiling when others laugh).

  A mechanism is needed to dynamically select the level that the robot should imitate according to the current social conditions and its own current needs and purposes (depending on whether imitation is currently a game, or a method of cutting down a search space, or a method for achieving social acceptance, among others). Imitation might not be possible at all levels at all times (unless elements of prediction are incorporated in the architecture), since frequently the purpose of an action might not be apparent at its onset.

- The robot should have a concept of its own body and of the body of the agent it is trying to imitate. These robot body images do not necessarily need to be designed in, and can be learned. We envisage that the two body images and their development will be closely linked (if not being instances of the same body schema), and in our work (Demiris and Hayes, 1996) we have suggested that this might be done in a distributed, topography-preserving way.

- Since the robot is perceiving its own body mainly through proprioception (and frequently through vision), while it is perceiving the other agent's through the external senses, there must exist a cross-modal matching mechanism that will perceive equivalences between the two modalities, and can translate between the two.

- There are two different forms of learning associated with imitation: learning to imitate and learning through imitation. In the former, the robot learns what its motor system has to do in order to do what the other agent is doing. In the latter, the robot learns by imitating the other agent, and associating perceptual experiences (environmental ones, and/or own ones, such as emotions, biological feedback from its own organism, among others) with this motor act.

## Robot Imitation Examples

We have performed two series of robot imitation experiments. One of them was performed on testbeds involving different types of robot heads and a human demonstrator (Demiris and Hayes, 1996; Demiris et al, 1997), where the experiments were aimed at examining the issues involved in movement imitation. The other series (Hayes and Demiris, 1994) involved two mobile robots of different morphology, where the experiments were aimed at examining the issues involved in learning through movement imitation.

### Movement Imitation

We are interested in understanding the mechanisms underlying imitation of movements in 3D space, so we engaged in a series of experiments involving a robot head imitating the head movements of a human demonstrator. The demonstrator performs a series of head movements positioned within the visual field of the robot head, and the robot imitates these movements. The technical details of these experiments are described in (Demiris and Hayes, 1996; Demiris et al, 1997); here we will focus on an issue particularly relevant to our discussion: due to the experimental scenario used, there will be different modalities involved during the perception and the execution of a movement pattern (the visual modality during perception and the proprioceptive modality during execution). This points out the necessity of designing a mechanism for bridging the two. In humans, such mechanisms have been hypothesised to exist at birth (Meltzoff and Moore, 1989), although several questions regarding the specifics of such mechanisms remain unresolved. For example, is the information derived from one modality transferred to the other one directly or is it stored in some intermediate a-modal representation? The segmentation of the input data (including the selection of the level to imitate, mentioned earlier, which has a strong influence on how the incoming data will be segmented) is one of the most difficult problems that the robot controller designer is facing. However, the study of imitation in natural systems is helping to resolve some of the difficulties, by suggesting that the generative system is actively involved in the recognition process. For example, recent neurophysiological research (Rizzollati et al, 1996) has indicated a strong link between the recognition and generation processes, at the neuronal level, through the discovery of 'mirror' neurons in the premotor cortex of monkeys, which are activated both during perceiving and executing certain actions. That means that the imitator's previous bodily experience influences the way it perceives the demonstrator's actions. Apart from reiterating the fact that past knowledge influences the way that current information is processed, this work emphasizes the role of embodiment in the way cognitive processes operate (Dautenhahn, 1997; Mataric, 1996).

### Learning through Movement Imitation

In this series of experiments, the purpose was to investigate how a robot can learn to negotiate the different types of corners in order to navigate through a maze. While one agent is knowledgeable about the task, the other is not, and is only equipped with the ability to imitate (follow) the first agent. The agents are placed in a maze, the first agent traverses the maze, and the second one follows right behind, associating the environmental states with the motor actions it is performing due to its imitation of the teacher. We will focus on a couple of important issues which are relevant to our discussion here that were made evident during this work (interested readers are referred to (Hayes and Demiris, 1994) for the details). These are essentially linked with the temporal dimension of the task. The first one of them is *when to imitate*: it is important for the imitator not to imitate the actions of the demonstrator (such as turning left or right in a corner) immediately, but rather when the imitator actually reaches that corner. The answer to this question might be task-specific, which implies that the imitator has to have some knowledge of the task in hand. The second one is *when to associate* what you perceive with what you do. Although some aspects of the answer to this are also task-specific, a partial solution might be given through the use of 'novelty detectors', which link the current action with previous knowledge that the imitator might have.

## Supporting the Imitation Process

Imitation is rarely a uni-directional activity, nor occurs in the absence of other learning processes. Infants and young children, not only imitate their parents and other peers, but are frequently imitated by them (Meltzoff, 1996), often engaging in mutual imitation games. There is also a close link between imitation, communication and cooperation (Klingspor, Demiris, and Kaiser, 1997): not only imitation can be used as a good way of developing communication (Billard and Hayes, 1997), and equipping the imitator with enough knowledge about a task so it can eventually engage in cooperation with other agents, but, reversely, communication can also help in the imitation process by influencing the way that the imitator understands the task in hand, so an appropriate level of imitation can be selected. For example, the imitator's action can be monitored by the demonstrator who can give feedback to the imitator on the quality of the imitation (providing the imitator with opportunities to learn how to imitate), but also on two crucial aspects mentioned above, *when to imitate*, and *when to associate*.

Learning by imitation is frequently combined with other learning processes, in which case the imitation process can help speeding them (e.g. (Schaal, to appear)). In addition, as we frequently mentioned in this paper, the imitator's own knowledge and capabilities, partially obtained by processes other than imitation (including trial and error learning), influence (hopefully facilitate) the way that the imitation process will take place.

These suggest that placing imitation architectures within a wider social learning context might help us solve some of the difficult issues in robot imitation that we outlined in this paper. If we want our robots to achieve the degree of imitation displayed in natural societies, we have to provide the robots with comparable levels of social support.

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## Available Demonstrations and papers

Video clips and papers on this and related work can be found at *http: // www.dai.ed.ac.uk / students / johnde / research.html*