An introduction to the imitative mind and brain

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Introduction

Imitation guides the behavior of a range of species. Advances in the study of imitation, from brain to behavior, have profound implications for a variety of topics including consciousness, the neural underpinnings of perception-action coding, and the origins of theory of mind. Human beings are the most imitative creatures on the planet. We create but we also imitate, and this combination provides us with a special (though perhaps not unique) cognitive-social profile. This book provides insights into the imitative mind and brain, its evolution, development, and place in adult psychology. In so doing, it addresses a longstanding puzzle about how "self" and "other" are coded within our brains.

Scope

Imitation has a long and rich history. From a historical perspective, the interest in imitation is much broader than the more focused treatment we give it in the present book. For example, in the past, the term imitation has been used in a number of different ways in domains as diverse as theory of art, theology, ethology, cultural anthropology, and psychology. Platonic and Aristotelian theories, drama, the visual arts, and music were conceived as using the imitation of nature (*imitatio naturae*) as a principle of aesthetic performance. In medieval theology, the notion of *imitatio christi* stood for the way man could regain resemblance with God (lost through the Fall of Man), by leading a life in humility, hardship, and poverty. In anthropology there has long been a focus on cultural variations caused by imitation-based practices of transferring customs and technologies across generations.

In this book, we do not use imitation in these broad senses, but rather in a narrower psychological sense. Our focus is not on imitative practices in art, religion, or technology, but rather on manifestations of imitation in individual behaviors. We realize, of course, that there is not really a

sharp demarcation between cultural and psychological uses of the term or between the respective areas of study. Still, science needs to be selective, and depends on focusing on certain things at the expense of neglecting some others. Accordingly, our emphasis is on imitation studied in the context of individual behavior, rather than the context of the spread of cultural practices across generations.

Further, within the broad field of imitation at the behavioral level, our focus will be on imitation performance, not on imitation learning. By this we mean that we will concentrate on the analysis of imitative acts referring to (relatively short-lived) body movements, instrumental, or communicative actions – and not to the role of imitation in the gradual build-up of (relatively long-lived) dispositions, like traits, attitudes, habits, or skills. The reason for selecting this particular focus is that we believe that much progress has been made in understanding the mechanisms underlying imitation of acts in recent years. And we believe that future breakthroughs in both cognitive science and neuroscience will continue to come in this area.

Imitation of behavioral acts is studied in many fields of inquiry, including developmental psychology, evolutionary biology, neuroscience, and experimental psychology. Often a major concern of research in these areas is identifying what species imitate, at what age imitation occurs, and what behaviors can be imitated. This style of research may be coined *What-research*. It is mainly interested in the conditions under which imitation occurs. Another major concern of research on imitation is to understand the functional architecture of the underlying mechanisms. This style of research may be coined *How-research*.

Again we realize that the dividing line is not really sharp. For example, in examining the imitation of facial gestures in human neonates, answers to the *What* also impose constraints on possible theories on the *How* of these imitative acts (Meltzoff, this volume). The same applies to the analysis of imitation in great apes (see Byrne, this volume; Whiten, this volume). Nevertheless the authors in this book emphasize *How*-questions over *What*-questions, and consider *What*-issues mainly in the service of helping to solve *How*-issues. Our focus will be on understanding mechanisms of imitation (*How*), not on studying the conditions under which people and animals make use of it.

In sum, this volume is deliberately selective in three major respects: we focus on imitation at the level of individual behavior, emphasize short-lived imitative acts, and are mainly interested in the functional architecture of how imitation is accomplished at the psychological and neurophysiological levels.

Contexts

The past twenty years have seen a renewed interest in imitation in at least four independent lines of inquiry.

One important contribution to reanimating scientific interest in the old theme of imitation came from developmental psychology. Meltzoff and Moore's (1977) paper on imitation of facial gestures in neonates opened up a new line of research and a discussion about the possibility of an innately shared code for perception and action. Initially, the debate focused on deconstructing Piaget's theory; but research on infant imitation quickly became a tradition in its own right, leading scientists to use imitation as a means of investigating the development of theory of mind, intentionality, memory, and clinical difficulties in atypical populations (e.g., Meltzoff, 1999; Meltzoff & Moore, 1997, 1998; Nadel & Butterworth, 1999).

A second line of rediscovery of the topic came from experimental studies in adult social cognition. Though the term imitation is often not used in that research, related concepts are often employed to account for findings in priming studies. The logic of these studies is surprisingly simple and straightforward. Participants who observe other people doing certain things or acting in particular ways tend to do similar things after the observation period (e.g., Bargh, 1997; Bargh & Barndollar, 1996; Dijksterhuis & van Knippenberg, 1998; Wegner & Bargh, 1998). These findings are usually interpreted as indicating automatic control of behavior and attributed to unconscious priming mechanisms. Priming is, of course, a candidate mechanism which may account for various other forms of imitation as well. But, we also must consider the possibility that what has become relatively automatic in adults may have developmental origins that once required more intentional control before becoming so "automatized."

A further new line of research came from the experimental analyses of human performance. In these experiments, people are required to do two things at the same time: perform certain actions by themselves and watch certain other actions being performed by somebody else (e.g., Stürmer, Aschersleben, & Prinz, 2000; Brass, Bekkering, & Prinz, 2001). These studies aim at specifying the interactions between action perception and action production – one of the crucial issues for understanding imitation.

Last, an important new context for studying and understanding imitation has emerged from neurophysiology and neuropsychology. Single-cell studies demonstrate that the brain has a number of sites where cells appear to be tuned to the perception of certain movements and/or

interactions with objects. Interestingly, some of these cells also have motor properties, that is, they are also involved in the production of the very same actions the animal performs itself (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Fogassi, & Gallese, this volume; Rizzolatti & Fadiga, 1998; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Likewise, brain-imaging studies have recently corroborated the evidence for common brain bases for action perception and action production (Decety, this volume; Decety *et al.*, 1997; Grèzes & Decety, 2001; Iacoboni *et al.*, 1999).

Given these independent contexts for a revival of interest in imitation, it is perhaps not surprising that most recently imitation has emerged as a new topic for those studying artificial intelligence. We believe that at the present juncture Nature's solution to the imitation problem is doing more to inform imitation by machines than the other way around. However, we agree that this may change in the not-too-far future, and indeed one of the hopes of this volume is that it will inspire more work in the artificial intelligence community on robotic learning by watching or imitation.

Issues

What do we need to understand when we want to understand imitation? What questions must theories of imitation address? Two basic issues need to be addressed by any theory of imitation performance. We need to understand how actions are perceived and we need to know how similarity can be effective between perception and action. We do not claim that the two issues are independent. In fact, whether or not they are viewed as independent is itself dependent on the answers given to the more fundamental questions.

How are actions perceived?

Understanding action perception entails (at least) three interrelated issues.

First, how is the stream of *ongoing* behavior parsed, that is, what information is used for segmenting the pattern of stimulation arising from watching other people's actions? At this level, action perception may not be any different from the perception of non-action events: perceptual systems have evolved for individuating objects (extended in space) and events (extended in time), and for subjecting these spatiotemporal "units" to further analysis (Tversky, Morrison, & Zacks, this volume). A debate is whether parsing the actions of our conspecifics is achieved through specialized neural machinery or more general visual analyses.

Second, once parsed, what determines the *level of granularity* at which actions are coded and identified? For instance, is the grasping of an object represented in terms of the abstract type "grasping an object of category *X*", or is it represented in terms of the concrete token, the specific kinematic pattern by which the arm moves in the act of grasping? To paraphrase an example from Wegner and Vallacher (1986): what is one actually doing while brushing one's teeth? Is one preventing cavities? Is one moving one's hand in a particular way, or is one just brushing one's teeth? Obviously, the level at which an action is identified has important implications for the imitation of that action: type imitation will be fundamentally different from token imitation, and imitation of the act of preventing cavities will differ from imitation of the act of moving one's hands in a particular way.

Third, once an action is parsed and identified, how far and in which ways does the perception of that action *go beyond the information given* in the stimulus? Taken literally, the stimulus information is just a complex pattern of visual information on the imitator's retina. Still, as we know from numerous studies, perceptual systems have evolved to go beyond the information given in various ways (e.g., Bruner, 1973). Therefore, perception is not just a matter of the proximal stimulus but also a matter of the information extracted and inferred from the stimulus. This is of particular importance for action perception. The information given (in the visual field) is a more or less complex kinematic pattern. However, the information perceived (in the imitator's visual world) is much richer. For example, as has been shown in a seminal study by Runeson and Frykholm (1983), it may include the dynamics behind the kinematics (i.e., the force applied in lifting a heavy object), or certain dynamically relevant properties of the objects with which the movement is interacting (like the weight of the lifted object).

Importantly, though dynamics are extracted from kinematics, we do not feel as though they are being derived or inferred from them. Rather, the information extracted from the stimulus pattern attains the same perceptual status as the information given in that pattern. Further, perceiving actions may even include the invisible goals the visible movements are striving for, as well as mental states like intentions or desires underlying those goals. All of these invisible things are readily extracted, as it were, from the visible stimulus. What, then, forms the basis of the imitator's imitation? Do people copy the kinematics or the dynamics of an action they see? Do they copy the movements they see or the goals/intentions "behind" those movements? When do people do one thing, and when the other?

How can similarity be effective between perception and action?

This is a fundamental problem of all brands of theories about imitation. Actually, it addresses a classical topic of psychology, which goes back to Aristotle's discussion of association principles. Aristotle distinguished between four such principles: succession, coexistence, contrast, and similarity. According to the principles of succession and coexistence, ideas get associated with each other when they repeatedly occur in close temporal or spatial contiguity. According to the principles of contrast and similarity, the same may occur with ideas that resemble each other (hot–warm) or oppose each other (hot–cold). In modern cognitive theories, a role for similarity is usually acknowledged in domains like reasoning or judgment (e.g., Hahn & Chater, 1998; Sloman & Rips, 1998).

However, similarity at first appears to be an inappropriate construct for conceptualizing relationships between perception and action. This is because when it comes to understanding relationships between afferent input and efferent output, the classical approach is that they are coded in different ways. Historically, this has led theorists to resort to rule-based rather than similarity-based operations, as described next.

Approaches

A brief look at classical approaches to perception-action relationships may help us understand why they had no room for similarity within their framework (sensorimotor views). It can also help us discern what requirements new approaches need to meet (cognitive views).

Sensorimotor views

Since the times of Descartes, sensorimotor views have been prevalent in philosophical, psychological, and physiological theories about how we know about the world and act on it (Descartes, 1664; cf. Prinz, 1997; Hommel, Müsseler, Aschersleben, & Prinz, in press). Until recently, sensorimotor views have been the gold standard in the brain and behavioral sciences. Following Descartes, these views postulated two incommensurate systems, one for the afferent processing of stimuli and another one for the efferent generation of movements. Accordingly, research on sensation and perception for the past several decades, if not centuries, has been neatly kept separate from research on movement and action.

On the afferent side, it has generally been believed that external objects and events lead to internal patterns of stimulation in sense organs, which, in turn, lead to sensory codes in the brain. On the efferent side, the story

goes the other way round. It starts with motor codes in the brain, which lead to patterns of excitation in effector organs, which, in turn, lead to movements. According to the logic of this scheme, sensory codes and motor codes have no way of talking to each other directly. Sensory codes and motor codes are incommensurate in terms of their contents. Sensory codes stand for patterns of stimulation in sense organs, while motor codes stand for patterns of excitation in muscles. Since they cannot talk to each other directly, some rule-based translation between the two is required. Rule-based translation serves to create mappings between stimuli and responses – be they innate (e.g., based on reflex arcs or instincts) or acquired (based on learned associations and their underlying neural networks).

Accordingly, in the experimental analysis of human performance, the metaphor of "translation" has become one of the most prominent theoretical notions to account for the operations underlying the mapping of responses to stimuli (Welford, 1968; Massaro, 1990). This metaphor stresses the incommensurability between sensory codes and motor codes, implying that both belong to separate representational domains and can, hence, only be linked to each other by way of creating arbitrary mappings.

An approach like this has no way to account for imitation in a functional sense, that is, based on similarity. If one believes that stimuli and responses are represented through sensory and motor features, respectively, the two sets of features are incommensurate – there is no way similarity, or overlap, could play a role in the mechanisms linking perception and action. (Still, since the incidence of imitation is too obvious to overlook, strict proponents of sensorimotor views have sometimes claimed that, though similarity cannot be functional between the imitator's perception and action, it can be functional in an observer's perception, who watches both the imitatee's and the imitator's action.)

A prominent example is provided by Gewirtz and Stingle's analysis of imitation learning (Gewirtz & Stingle, 1968; cf. Prinz, 1987). This account proposes that infants learn imitative responses in the same way as all other behaviors, that is, without any functional support by similarity between stimuli and responses. Instead, imitative responses initially occur by chance. They immediately get reinforced by observers (e.g., parents), who are capable of noticing their imitative character. Therefore, functionally speaking, the infant does not copy the parent, and certainly does not intend to copy, but rather the parent reinforces the infant on occasions when s/he happens to behave like him/herself (or some other model). According to this view, similarity is recognized by the observer who watches an imitator performing the same action as somebody else – but it does not play a functional role between the imitator's perception

(of somebody else's action) and control of his or her own action. Accordingly, the true story for the imitator is a story about rule-based mappings – under conditions where the rules teach the imitator to act in a way that, from an observer's point of view, looks like the way the model acted immediately beforehand. Obviously, an account like this, though it may possibly account for certain learned imitative responses, cannot explain the occurrence of newborn imitation or the imitation of novel behaviors by adults.

Cognitive views

Recent cognitive views of relationships between perception and action have developed a way to overcome the limitations of the classical Cartesian view of separate and incommensurate systems. Cognitive views provide room for both rule-based translation and similarity-based induction. On the one hand, they acknowledge a strong role for rule-based mapping in order to account for many forms of learning. However, they also acknowledge a role for similarity-based matching that may operate in parallel to rule-based mapping.

Similarity-based matching takes care of two things at once: (a) extracting, from the perception of the model's ongoing action, certain features that go beyond the sensory information given and (b) using this extract for planning and controlling the imitator's own actions. Cognitive approaches invoke a common representational domain for perception and action – that is, for representing the model's actions and planning the imitator's own actions. Obviously, in order to be functional, common representations need to refer not only to body movements proper but also to the representation of other bodies and one's own body and the way the perception and control of one's own bodily activities are related to each other. Further, common representations may even refer to invisible physical and mental entities "behind" visible bodies and their movements, like forces or intentions. Within the common representational domain, perception and action can talk to each other directly in the same representational language, and there is no need for translation anymore. One can induce the other by virtue of similarity. Meltzoff's AIM mechanism (Meltzoff, this volume) or Gattis, Bekkering, and Wohlschläger's goal-directed theory (this volume) provide two examples of models of imitation in which this basic logic is embodied (see also Prinz, this volume).

Over the past ten years, the view that perception and action share certain representational resources has gained strong support from neurophysiology and brain imaging (see Rizzolatti, this volume; Decety, this volume). We can no longer rigidly maintain the neat separation of the domains of perception and action, on which we have lived so comfortably

since the times of Descartes. This may be bad news for the Cartesian doctrine, but it is good news for the study of imitation. It is fitting that interest in imitation is waxing when the authority of Descartes' doctrine of incommensurability is waning.

The time for studies of imitation has arrived. Imitation is readily studied at multiple levels by interdisciplinary research teams. It informs us about perception, motor control, the mechanisms underlying perception-action coupling and self–other relations. Over the next decade it promises to become a prototypical case of interdisciplinary research on brain-behavior relations and to shed light on both cognitive questions and those aimed at understanding intersubjectivity.

Overview of the volume

This volume is divided into three parts. Part I concerns developmental and evolutionary approaches to imitation. It focuses on theories about the origins of the imitative mind as well as empirical findings from typically developing human infants, children with autism, and great apes. Part II presents cognitive approaches to imitation using adult subjects. It highlights what imitation tells us about perception-action coding and the body scheme. Part III analyzes the neural underpinnings of imitation. Exciting new work on "mirror neurons" and shared cortical regions for the observation and execution of action are presented. Taken together, the chapters provide a comprehensive analysis of the burgeoning multidisciplinary field of research on imitation.

In Chapter 1 Meltzoff describes his work on imitation in human infants. In order to account for imitation by infants, he postulates a "common metric" between the observation and execution of acts. The importance of his studies on newborns is that they document a basic link between perception and production that is not forged through postnatal experience. This fits together well with the reports of "mirror neurons" and adult neuroimaging studies discussed in Part III of this book. Meltzoff also discusses child development after the newborn period. He proposes that infant imitation is a precursor to developing empathy toward others and a theory of mind. The chapter outlines a psychological mechanism for this important developmental transition.

Nadel examines the functional uses of imitation in typically developing children and children with autism. She presents data and theory that the preverbal child uses imitation to initiate social exchanges and to respond to other's initiations. Nadel reports fascinating data about the imitative deficits in children with autism and provides an analysis of how imitation may serve as a foundation for language and communication.

Asendorpf examines the relation between early imitation and self-awareness in the second year of life. His provocative studies indicate links between the development of self recognition (e.g., mirror recognition studies) and imitation. His emphasis on the communicative aspects of imitation complements those of Nadel.

Heimann summarizes research carried out in Sweden over the last fifteen years showing that newborns imitate a range of gestures, and also showing individual differences in imitative reactivity in infancy. Heimann was the first to document such early-emerging individual differences, and he describes interesting correlations between early imitation scores and subsequent functioning at older ages. This chapter foreshadows Part III of the book, which discusses the profound deficits in imitation manifest in certain adult syndromes (e.g., apraxia).

Rochat sets his sights on the development of the notion of "self" in infancy and believes that imitation is a tool for expanding the notion of self both for the adult scientist and the child. The crux of his chapter is that contemplation of the self as object (self-objectification) is a process emerging from young infants' propensity to reproduce their own actions and engage in self-imitation. From the repetition of one's own actions, the self becomes objectified, becoming both an embodied experience and a potential object of thought (i.e., self-reflection). Rochat, like Meltzoff and Nadel, emphasizes how imitation is used by the child to prompt development, going beyond the initial state.

Whiten reports his pioneering work on imitation in chimpanzees. The rationale for the experimental design is essentially ethological, with the tasks designed as analogues of foraging problems in the wild. Whiten constructs "artificial fruits" that duplicate features of real fruits by requiring the animal to perform a sequence of manipulations to successfully obtain the food reward. His experiments suggest that chimpanzees and young children can imitate both the shape and sequential structure of the model they witness, with children generating higher fidelity copies than chimpanzees. His chapter also includes comparative analyses of imitation in typically developing children and children with autism.

Byrne reports empirical and theoretical work based on many years of studying gorillas in the wild. He is concerned with the animals' ability to discern the principles and organization of observed behavior and thereby to selectively copy novel behavioral structure. Byrne explores the cognitive underpinnings that are necessary for what he has dubbed "program-level" imitation. The possibility of imitation by great apes has stirred a great deal of debate and discussion; Whiten and Byrne are among those who have done the most careful studies to date on this important topic.