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Determinants of gestural imitation in young children

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DETERMINANTS OF GESTURAL IMITATION IN YOUNG CHILDREN

Volume 1

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Mihela Erjavec
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Thesis submitted towards a Ph.D.

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Summary

Generalised imitation has often been cited in the behaviour analytic literature as a paradigm case of a higher-order response class. However, its determinants have not been established. When, as is the case in published experimental studies of children's imitative performances to date, the to-be-matched behaviours are actions on objects, many non-imitative processes can result in apparently emergent matching. Such confounding sources of control are minimised when the target behaviours are arbitrary gestures.

The present experiments explored the matching of (i) arbitrary actions on novel objects with minimal affordances in 3 infants (9 - 15 months), and (ii) gestures alone in 13 infants (15 - 25 months), and in 20 young children (24 - 42 months).

In Experiment 1, the infants' performance of the target actions was measured firstly in response to each of four novel objects (Baseline) and next to the target action (Modelling) on each of these objects. In Experiments 2 and 3, participants' unreinforced responses to target behaviours, and their intermittently-reinforced responses to four behaviours that featured in their trained baseline matching relations, were measured. No evidence of higher-order matching was found; rather, the performances of the infants in Experiments 1 and 2, and of the young children in Experiment 3, could be explained in terms of generalisation of extra-experimentally trained matching repertoires.

Infants' higher-order matching abilities were directly tested in Experiments 4 and 5. Following training of four baseline matching relations, and identification of four target behaviours that the infants failed to match, they were trained to produce the target behaviours in the absence of the corresponding modelled behaviour. Infants' unreinforced responses to the modelled target behaviours, interspersed with modelling of the intermittently reinforced baseline behaviours, were then re-tested. The data showed no evidence of higher-order matching and suggest that infants' higher-order matching abilities, not previously directly tested, have been overestimated in the behaviour analytic literature.
CHAPTER 1

Introduction: Imitation, History and Definitions

The Experimental Study of Imitation: A Theoretical Overview

Many contemporary authors have traced the long history of discussions and experiments on imitation back to the 19th century debates between Darwin, Romanes, and Wallace, who were attempting to support their conjectures on the evolution of intelligence with anecdotal evidence about the alleged imitative abilities of humans and non-human animals. Miller and Dollard (1941) went even further back and enlisted Aristotle as the first to ascribe an important role to imitation.¹

It has been acknowledged that contemporary comparative empirical work on imitation reflects the designs and interests of early learning theorists and experimental psychologists, especially Morgan and Thorndike (see

¹ Aristotle wrote that, "[Man] is the most imitative of all living creatures, and through imitation learns his earliest lessons, and no less universal is the pleasure felt in things imitated." (Miller & Dollard, 1941). By contrast, according to Nadel and Butterworth (1999), Plato argued that imitation holds danger to individual identity and for self-consciousness, and that mimesis limits intelligence and leads to depravity.
Chapter 1

Introduction

Byrne & Russon, 1998; Galef, 1988, 1996; Visalberghi & Fragaszy, 1990; Whiten & Ham, 1992). Early psychologists considered imitation to be a primitive and relatively unintelligent path taken mostly by "savages, young children, monkeys, and retarded adults" (Visalberghi & Fragaszy, 1990, paraphrasing Romanes, and see Footnote 1), but there has been a steadily growing view that imitation may require complex cognitive abilities.

In the contemporary developmental literature, much of the early work was inspired by Piaget's (1952) theory, which linked the development of imitative abilities to what he defined as sensory-motor stages in the first two years of life. Piaget emphasized the following distinctions:

1. Immediate versus deferred imitation.
2. Imitation of known acts versus "generative" imitation (of novel acts).
3. Imitation of acts visible for the imitator (e.g. hand movements) versus imitation of acts that are "invisible" for the imitator (e.g. facial gestures).

Imitation became a truly popular topic of study in the 1970's, and has remained so ever since (see Nadel & Butterworth, 1999). A critical review of contemporary developmental research and theories is presented in Chapter 4.

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2 Whiten and Ham (1992) suggested that the presently influential 19th century legacies include: (i) classification of imitative phenomena, (ii) the experimental paradigms, (iii) apparent primate superiority, and (iv) contrasting non-vocal and vocal imitation.
In the behaviour analytic literature, the study of (generalised) imitation started in the 1960's with the work of Baer and colleagues (Baer & Sherman, 1964; Baer, Peterson, & Sherman, 1967). Behaviour analytic research concentrated on the following topics:

1. The conditions under which children show matching of behaviours when external reinforcement is not given for doing so. (Note: The term "matching" is used throughout the present thesis to denote that, in an episode, an observer produced a behaviour that is physically similar to that of a model; the term "matching" is purely descriptive).

2. Establishing (training) matching in special populations, with initially non-imitative individuals.

A critical review of behaviour analytic theory and data is presented in Chapter 3.

***

Contemporary researchers frequently refer to the fact that imitation has long been regarded as an interesting topic, relevant to many aspects of learning, and worthy of discussion and investigation. However, such is the diversity of paradigms and theories that have been put forward in the past hundred years, that it is difficult to decide between the competing
definitions of what should be considered to be imitation and what should not.3

The study of imitation has remained vibrant in comparative psychology up to the present. Indeed, theoretical distinctions between behaviours that qualify as imitation and those that do not, and the experimental controls needed to identify instances of imitation, have been continuously debated and refined beyond those employed in developmental and behaviour analytic studies. Further, comparative researchers have attempted to share their perspectives with researchers from other traditions, and, at present, developmental psychologists are beginning to participate in this exchange (see Want & Harris, 2002, and commentaries). Much of the discussion concerning what is not imitation, presented in Chapter 2, is illustrated by reference to comparative data.

To summarise. At present, there exist innumerable theories of imitation and a bewildering range of terms referring to mechanisms of imitative and other related forms of learning that are said to explain how an observer produces behaviour that resembles the behaviour of a model. These terms include (the present list is by no means exhaustive!): action-level imitation, action-perception links, active intermodal mapping, active equivalence mapping, affordance learning, allelomimetic behaviour,

3 In many debates, theorists with mutually exclusive paradigms easily traced their preferred approaches way back, cited the lists of honourable predecessors, and so "showed themselves to be in the right" (see Byrne & Russon, 1998; Galef, 1988; Heyes, 1999; Whiten, 1999).
behavioural matching, contagious behaviour, copying, cross-modal matching, emulation, final-state re-creation, generative perceptual processes, generalised imitation, goal emulation, goal enhancement, goal imitation, hierarchy imitation, identification, imitation, imitative copying, intelligent imitation, instinctive imitation, intermodal equivalence matching, kinaesthetic-visual matching, local enhancement, matching, matched dependent behaviour, mimesis, mimetism, mimicking, mimicry, modelling, observational conditioning, object movement re-enactment, observational learning, on-line coupling, on-line matching, operant matching, program-level imitation, protocultural processes, pseudo-imitation, pseudo-vicarious instigation, reflective imitation, response facilitation, response priming, response-stimulus learning, response-reinforcement learning, same behaviour, sequence imitation, single stimulus learning, social enhancement, social facilitation, social influence, social learning, social transmission, stimulus enhancement, stimulus-stimulus learning, suggestibility, true imitation, vicarious conditioning and reinforcement, vicarious experience, and vicarious instigation.⁴

⁴ As noted by Galef (1988), the sheer number of different terms may have created a false impression that there is much knowledge regarding these putative social learning mechanisms, whereas little research had actually been performed on most of them. Many authors who contributed to this list of terms have failed to appreciate that, because of lack of data, their "explanations" were no more than conjectures.
In the following paragraphs, the most influential definitions of imitation from the comparative, behaviour analytic, and (cognitive) developmental literature are examined in order to single out recurring themes and issues.

Definitions of Imitation

"Language, being a folk creation, would not be expected to provide a very exact discrimination of the forms of actions which it lumps under the general term 'imitation'. It is, indeed, this inclusiveness of common speech which poses the scientific problem and demands that the scientist make further and more exact distinctions." (Miller & Dollard, 1941, pp. 91)

Comparative Psychology

Many comparative researchers have adopted Thorndike's (1911) brief definition of imitation as, "learning an act from seeing it done" (cited in Galef, 1988). Others preferred Thorpe's (1963) slightly more elaborate description of "true imitation" as, "the copying of a novel or otherwise improbable act or utterance, or some act for which there is clearly no instinctive tendency" (cited in Zentall, 1996).

The conventional approach to the study of imitation in comparative psychology was—and still is—to strengthen the core definition by excluding the alternative phenomena that could result in "false positives" (Heyes, 1996). This practice seems to have been useful in linking and contrasting imitation with other forms of learning, and in promoting cautious
interpretation of the findings (see Chapter 2).

With an eye to the everyday use of the term, and drawing on the publications of Baldwin (1902), Morgan (1900), Guillaume (1925), and Piaget (1952), Mitchell attempted to arrive at an exhaustive and precise definition of imitation, said to occur when:

"(i) something C (the copy [behaviour]) is produced by an organism and/or machine, (ii) where C is similar to something else M (model [behaviour]), (iii) registration [observation] of M is necessary for the production of C, and (iv) C is designed to be similar to M." (Mitchell, 1987, pp. 198)

However, in response, Visalberghi and Fragaszy (1990) argued that "design" cannot be observed. They proposed that the Mitchell definition should be modified by including novelty as a pragmatic criterion, thus adding, "(v) C must be a novel behaviour, not already organised in that precise way in the organism's repertoire." These authors also argued that any operational definition should be used as a reference only, and that data should be discussed individually within each paradigm.

In a more recent and wordier attempt to pool the diverse criteria that have been considered as both necessary and sufficient for imitation to be demonstrated, Russon and colleagues wrote:

"True imitation copies the form of modelled behaviour, not simply its aims or consequences; it is goal-directed; it can generate new behaviour for which the learner has no instinctive tendency; in true imitation, observation is both necessary and sufficient to copy novel behaviour; the performance of imitative
behaviour can be temporarily deferred; and true imitation is a generalised ability applicable across problems." (Russon, Mitchell, Lefebvre, & Abravanel, 1998, pp. 105)

As illustrated by these examples, one of the recurring themes has been the novelty requirement. Two other important points are that: (i) observation of the model's behaviour ought to be necessary and sufficient for imitation, and (ii) imitation ought to generalise across behaviours.

Russon and colleagues write that imitation ought to be goal-directed; the issues gaining prominence in the contemporary debates include goal-directedness, intentionality, and understanding. To begin with comparatively weak claims concerning these additional factors, several authors have proposed that understanding may be necessary for the imitation of instrumental tasks (such as the use of tools). In these tasks, the observers are supposed to learn the new "rules" (e.g. how new tools can be used), as opposed to "rote" learning or "mimicking" (e.g. handling the tools without understanding their function). It has often been asserted that such learning cannot be accomplished if the tasks are far above the organism's competencies (see Visalberghi 1997, 1999). This argument can be partly reduced to saying that what an organism can achieve through imitation depends on its previous knowledge (developmental history), which is presumably true of all learning. The proposed distinction between the learning of "rules" and "rote copying" is linked to questions regarding the organisation of behaviour, which themselves transcend the study of imitation and social learning, and are in principle amenable to empirical investigation.
A stronger claim has been made by Tomasello and colleagues, who asserted that imitation requires some understanding of the intentions behind others' actions, and on this basis can be differentiated from other forms of (social) learning (Carpenter, Akhtar, & Tomasello, 1998; also see Meltzoff, 1995; Tomasello, Kruger, & Ratner, 1993). Further, many authors have considered imitation to be linked to what has been termed "pretense" (Whiten, 1995) and "theory of mind" (see Heyes, 1998, and commentaries; also see Whiten, 1993), and to involve complex, second-order representations (Heyes, 1993; Whiten, 1996).5

Not surprisingly, there has been much debate on whether goal-directedness and goal-, intention-, and mind-reading should be included in the definitions of imitation. Several authors expressed the view that it is unreasonable to insist that inferring others' goals and intentions is necessary for all imitation, because these would not always be transparent, as, for example, in the modelling of arbitrary actions which do not produce definitive environmental consequences (see Custance, Whiten, & Bard, 1995; cf. Bekkering, Wohlschlager, & Gattis, 2000). In a similar vein, Noble and Todd (1999) have pointed out that invoking the need for "identification", whereby observers must adopt the attitudes and

5 Whiten (1996) presented the following argument: in order to produce a good imitation, an organism needs to operate a program of action that replicates that of a model. Imitation therefore involves two representations: a first-order program (action plan) controlling the model's actions, and the second one in the imitator, which can therefore be seen as a second-order representation to the extent that it replicates the model's (first-order) representation.
behaviours of a model (e.g. Bandura, 1969), or of perspective-taking, or intentionality, was no more than an exercise in re-labeling imitation and not an explanation of how these putative prerequisites may themselves be acquired. Similar criticisms have been made in the behaviour analytic literature (e.g. Baer & Deguchi, 1985; Gewirtz, 1971; Gewirtz & Stingle, 1968; Masia & Chase, 1997). Heyes (1994) has also pointed to the circularity of argument involved in defining imitation in terms of a hard-to-detect, under-defined property termed goal-directedness.

Overall, it seems clear that many comparative theorists have shared the intuition that imitation involves a qualitatively different learning mechanism from that involved in the other forms of learning; their definitions can be interpreted as attempts to formalise this intuition.

Heyes, however, has challenged the notion that imitation involves learning that is qualitatively different from all other forms of learning (see Heyes, 1994, 1999). Her alternative definition, from the framework of contemporary associative learning theory, classified observational learning as a subset of response-reinforcement learning, said to share the mechanisms of other non-social and social learning. According Heyes, observational learning can be said to occur when modelling exposes the observer to the relationship between a response and a reinforcer, and this exposure at one time results in behaviour change in the observer that can be detected at a later time. Unlike the others, this definition leaves room for all possible behavioural effects of observation (it is not restricted to full reproduction of modelled behaviour); therefore, it includes phenomena that other definitions do not. Further, Heyes assumed that reinforcement
in all such learning episodes must be observable, or extrinsic; this is also at variance with most notions of imitation.

**Behaviour Analysis**

Behaviour analysts have also argued that imitation need not involve mechanisms that are qualitatively different from those used to explain other forms of operant learning (e.g. Skinner, 1953). For example, Baer and his colleagues wrote that:

"Any behaviour may be considered imitative if it temporarily follows behaviour demonstrated by someone else, called a model, and if its topography is functionally controlled by the topography of the model's behaviour. Specifically, this control is such that an observer will note a close similarity between the topography of the model's behaviour and that of the imitator. Furthermore, this similarity to the model's behaviour will be characteristic of the imitator in response to a wide variety of the model's behaviours. Such control could result, for example, if topographical similarity to a model's behaviour were a reinforcing stimulation for the imitator." (Baer, Peterson, & Sherman, 1967, pp. 405)

Gewirtz and Stingle wrote, briefly, that:

"The term *generalized imitation* can be used when many different responses of a model are copied in diverse situations, often in the absence of extrinsic reinforcement." (Gewirtz & Stingle, 1968, pp. 374-375)

Poulson and Kymissis wrote, more formally, that:
"Generalised imitation refers to behaviour that: (a) is topographically similar to that of a model, (b) is controlled by virtue of fine-grained topography of the model's behaviour, and (c) occurs in the absence of environmental consequences for its occurrence, or occurs under consequences that were reduced from those during training." (Poulson & Kymissis, 1988, pp. 325)

As seen in these examples, the behaviour analytic definitions of imitation showed a deliberate exclusion of the strongest cognitive terminology, and a noteworthy absence of the novelty requirement (although implicit in the studies is the notion that in order to demonstrate generalised imitation, behaviour relations not trained as matches in the experimental setting must be tested; see Chapter 3).

**Developmental Psychology**

It has been said that the lack of a precise and agreed definition of imitation hampered developmental research from its earliest days (see Valentine, 1930, cited in Nadel & Butterworth, 1999). This trend persisted: contemporary developmental publications seldom contain any operational definitions of imitation. In the developmental literature, imitation has been investigated in its broadest sense of "doing what a model does". In a typical example, Meltzoff and Moore defined imitation as follows:

"Imitation is an innate capacity of the human species. Imitation is something infants bring to their very first interactions with other people. It is not the product of learning, but rather a species-specific mechanism for social learning and the transmission of acquired characteristics from one generation to the next."
(Meltzoff & Moore, 1999, pp. 9-10)
Evidently, this kind of definition does not establish the criteria for exclusion of "false positives" in the experimental study of imitation. In practice, some of the experimenters did include controls for several non-imitative matching mechanisms (e.g. Meltzoff, 1988b; Meltzoff & Moore, 1983; and see Chapter 4); however, these have not been incorporated into their theoretical accounts.

In a recent theoretical paper, Butterworth (1999) started with a minimal definition of imitation (equivalent to that of Thorndike, 1911, cited above); he then discussed the novelty requirement (after Thorpe, 1963, also cited above) and the exclusion of non-imitative matching mechanisms (after Whiten & Ham, 1992, see Chapter 2). It is revealing that this developmental author did not cite other developmental theorists. Butterworth's own synthesis, presented at the end of these discussions, is once again vague (as compared to those of comparative and behaviour analytic authors). Thus he concluded that:

"(i) The prototypical case of imitation is when one individual voluntarily reproduces behaviour observed in another who acts as a model for the form of a behaviour. (ii) It involves an essential quality of transfer of information which forms the basis for establishing behavioural correspondence. (iii) Imitation in humans may be related to mimicry in its broader biological sense in ensuring that infants come to "blend" with their social surroundings." (Butterworth, 1999, pp. 68)
Overall, the developmental literature to date has not produced any exact definitions of imitation.\(^6\)

**A Minimal Definition of Imitation**

Whiten (1999) suggested that nobody should attempt to legislate what "true" imitation is, but all should state precisely what they mean when using this term.\(^7\) For the purpose of further discussion, a minimal definition of imitation is suggested next. This definition, derived from the constraints that are common to the definitions cited above, is compatible with most comparative and behaviour analytic writing. It omits the more vague, cognitive terminology of some comparative writing; it adds the

\(^6\) A likely reason for this difference is as follows: comparative authors have assumed that imitation may be impossible for most non-human animals; consequently, they sought to establish the precise criteria under which imitation could be unquestionably demonstrated. Behaviour analysts, wary of emergent learning, sought to identify the variables that were functional in any generalised imitation learning episode; precise definitions and descriptions were seen as necessary for this. By contrast, developmental authors have assumed that humans can imitate, and have never considered reinforcement to be crucial for human learning. Consequently, they took a lenient approach to "false positives" in their matching data; they concentrated their efforts not on unambiguous definitions of imitation, but on a multitude of theories that have incorporated imitation as one of the learning tools available to young children.

\(^7\) He also expressed his hope that a consensual usage, preferably not too distant from the everyday one, will emerge in the future.
novelty requirement to the behaviour analytic definition of Baer and colleagues. Thus:

*Imitation can be said to occur when: (i) an observer emits behaviour that is similar to that of a model, after seeing the model's behaviour, (ii) the behaviour in question is novel for the observer, (iii) the observer's behaviour is directly caused by seeing the model's behaviour—and not by something else—and (iv) no external reinforcement is necessary.*

In developmental psychology, all agree that imitation enables children to learn new, conventional behaviours efficiently, by observing the actions of their caregivers and peers (e.g. Barnat, Klein, & Meltzoff, 1996; Hanna & Meltzoff, 1993). Therefore, the present minimal definition is compatible with the developmental literature:

1. Children are said to produce behaviours that bear good resemblance to those that they have seen others perform; their responses that do not show good resemblance to the modelled behaviours would not be labelled as imitation by most researchers (cf. Gleissner, Bekkering, & Meltzoff, 2000; and see Chapter 8).

2. Children are said to imitate a range of novel behaviours; if they imitated only the behaviours that they knew how to perform already, their repertoires would not increase through imitation.

3. It is their social partners—and not other features of the environment—that directly determine children's imitative behaviours. The exclusive functional control of others' behaviour is certainly assumed in all discussions, if not always controlled for in practice (cf. Meltzoff, 1988a,b; and see Chapter 4).
As discussed above, most definitions of imitation feature the following criteria: (i) the novelty of behaviours that are learned through imitation, and (ii) the similarity between observer's and model's behaviour. The two related concepts of behavioural novelty and similarity are discussed next.

**Novelty of Target Actions**

Many authors have suggested that novelty of the modelled behaviour is one defining characteristic of imitation (e.g. Byrne & Russon, 1998; Carpenter, Nagell, & Tomasello, 1998; Hayne, 1998; Tomasello, Kruger, & Ratner, 1993b). By contrast, Heyes (1993, 1995) has argued that distinctions between known and novel actions should not be made, because: (i) it is not possible, in practice, to distinguish between entirely novel behaviours and re-combinations of known behaviours, and (ii) there is no theoretical reason to believe that complex mechanisms of imitation differ along the dimension of novelty (also see Heimann, 1998). Mitchell (1987) proposed a distinction between "imitation" of known acts and "imitative learning" of novel acts.

All agree that novelty cannot be defined in absolute terms. Variability is inherent in all behaviour; no two acts of the same individual are—at the very finest level of analysis—ever the same (Boesch, 1993; Whiten & Custance, 1996). Most "novel" acts are built by either modifying other behaviours, or by adapting these to novel tasks, or by recombining them (Skinner, 1953; Whiten, 1998). Heyes' (1995) reluctance to accept the criterion of novelty reflects the real difficulty that any experimenter faces in attempting to map the entire behavioural repertoires of their
participants. Even if such knowledge were attainable, the experimenter would still be left with the task of differentiating between the known behaviours and those that may be slightly different from them, and hence novel in some respect.

Byrne and Russon (1998) argued that it is easier to assess novelty in multiple-step procedures, where novelty lies in the novel arrangements of known actions, rather than in the learning of new, basic actions (also see Whiten, 1998). It has been suggested that directing known behaviours to novel objects ought to count as novel behaviour (Visalberghi & Fragaszy, 1990; Whiten & Custance, 1996). Meltzoff (1988a) suggested that a model's act (an object manipulation in this argument) can be novel in at least six different senses: (i) it has never before been seen by the observer; (ii) it has never before been performed by the observer; (iii) it is infrequent in the observer's repertoire; (iv) it has not been imitated before by the observer; (v) it has not been performed on a particular object by the observer; and (vi) it occurs with near-zero probability in experimental baseline measurements of observer's behaviour.

In all of the reviewed strands of literature, the assessment of novelty—if any were performed at all—consisted of near-zero baselines prior to modelling of a target action (the weakest sense of novelty in Meltzoff's classification). Several authors have argued that this was sufficient (e.g. Butterworth, 1999; Byrne & Russon, 1998); none has offered any alternatives.

In the present thesis, novelty has been accepted as both a theoretical
requirement for truly generative imitation and a pragmatic criterion (as a control for extra-experimental learning). The term is used in several different ways, and never without clarification. For example, in some of the experimental chapters, the term "novel" is applied to target behaviours which have not been directly trained as matches to the corresponding modelled behaviours. This distinction—not made in any of the published studies—is deemed theoretically important; the reasons for this particular use of the term "novelty" are explained in Chapter 3.

**Similarity between Observer's and Model's Behaviour**

As is the case with novelty, the similarity between two acts cannot be judged in absolute terms. Many agree that it would be naive to expect perfect correspondence—even if such a thing could be measured in some way—between the behaviours of an observer and a model (see Vogt, 1999; Vogt & Carrey, 1998). On the other hand, the observer's responses which show only weak resemblances to the model's behaviour may not justify the claims of imitation (Whiten, 1999).

The responsibility for establishing criteria by which to judge similarity rests with the experimenters; therefore clear criteria for coding and descriptions of the "imitative" responses are necessary. Further, the "approximate" responses that an observer emits to modelling of "novel" behaviours ought to be assessed against the observer's known repertoire, in

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8 Independent (blind) coders ought to be used for scoring the matching data.
order to ascertain their novelty. However, most of the developmental and other publications have not presented such detailed descriptions (e.g. Gleissner, Bekkering, & Meltzoff, 2000; and see Chapter 8); virtually none has discussed the relationship between the participants' apparently novel, imitative responses, and their existing behavioural repertoires (see critiques in Chapters 3 and 4).

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As noted earlier, non-imitative social learning processes have been debated in the comparative literature throughout its history. Recently, developmental theorists have begun to take note: Want and Harris (2002) have argued that the distinctions between imitation and other, non-imitative forms of learning ought to be made in the developmental literature also.

In the following chapter, non-imitative learning processes that can lead to an observer's matching of the behaviours of a model are discussed, with examples and illustrations mainly taken from the comparative literature. Controls for these non-imitative processes that need to be included in all experimental studies of imitation are discussed. The list of necessary experimental controls for "false positives" is then used, together with the present definition of imitation, to critically evaluate data from behaviour analytic (Chapter 3) and developmental (Chapter 4) studies.
CHAPTER 2

Non-Imitative Matching Processes: A Review of the Comparative Literature on Imitation

To start a developmental thesis, concerned with matching and imitative abilities of human infants and young children, by reviewing the literature that presents and discusses the findings from the experiments performed (mainly) with non-human animals, may seem unusual.

Behavioural analysts would, in principle, agree with this approach, because of the traditional emphasis on the continuities between non-human and human learning. In practice, as discussed in the next chapter, the behaviour analytic literature on matching and generalised imitation contains few references to, and even fewer experiments about, the matching abilities of non-human participants. Further, behaviour analytic writings on generalised imitation contain virtually no references to either comparative or developmental data (e.g. Poulson, 1999).

Unlike the (cognitive) developmental literature reviewed in Chapter 4, most comparative writings contain a healthy insistence on parsimony in explaining matching data from any species (Visalberghi, 1989). Consequently, researchers from the comparative tradition have proposed a multitude of theoretical distinctions and experimental controls that are
necessary to distinguish imitative behaviour from non-imitative learning processes. The present critical review of these distinctions suggests a list of necessary and sufficient controls that need to be employed in imitation studies with human (and non-human) participants. It also provides the terminology for a critique of human data, presented in the following chapters.

**Behavioural Contagion and Observational Conditioning**

It has been demonstrated that, for many species, small sets of behaviours can be elicited by the corresponding acts of conspecifics. Terms used by various authors to describe this phenomenon have included behavioural contagion, mimesis, allelomimetic behaviour, and instinctive imitation. Ethologists classify these behaviours as "fixed action patterns", and the eliciting stimulations of others' behaviour as a social subset of innate releasing mechanisms (Galef, 1988).

Examples of *behavioural contagion* in the comparative literature include synchronised courtship, co-ordinated consummatory behaviour, and predator evasion and flocking in herding animals (Zentall, 1996). While itself limited in scope, behavioural contagion can promote rapid acquisition of important behaviours. For example, Mineka and Cook (1988) demonstrated learned fear and avoidance in inexperienced monkeys who were allowed to observe experienced conspecifics' reactions. In this much cited study, contagious fear reactions coupled with exposure to relevant (visible) stimuli were shown to result in classically conditioned fear of real and toy snakes, but not of "neutral" stimuli such as flowers, showing the
"preparedness" of some associations over others. This kind of learning attracted several labels, such as observational conditioning and (pseudo)vicarious instigation (Galef, 1988).

Heyes (1994) argued that observational conditioning should be classified as a subset of stimulus-stimulus (Pavlovian) learning, and subdivided into four subgroups (the combinations of excitatory or inhibitory with aversive or appetitive). Others have also suggested that behaviours that tend to co-occur in a group over a variety of situations may become classically conditioned releasers (Galeff, 1988; Noble & Todd, 1999), although only very consistent pairings would be expected to produce such effects.¹

It has been suggested that behavioural contagion could explain some of the "neonatal imitation" data with human infants. In brief (see Chapter 4 for a full review), it has been reported that frequencies of small mouth movements (such as tongue protrusion and mouth opening) in neonates increase after exposure to an adult modelling such gestures (e.g. Meltzoff & Moore, 1983). Provine (1989, 1996) reported a series of studies showing that adult humans' yawning and laughter are (stereo)typical "fixed action patterns" that can be released by a range of visual and auditory stimuli. Provine argued that matching of a limited set of facial features in neonates could occur as precedents of these contagious behaviours; some contagion

¹ Further, some commonly produced acts (e.g. feeding behaviours) of others could, through regular co-occurrence, become established as discriminative stimuli for the corresponding behaviours of the observers (see Skinner, 1953, and the later heading on trained matching).
of affect in humans would also not be surprising, as it occurs in other primates. In line with this hypothesis, it has been shown that the releasing stimuli for the prominent neonatal matching of tongue protrusion need not be social at all (Jones, 1996).

Occasionally, researchers working with human infants have used non-social stimuli sharing some properties of facial gestures, such as gaping, protrusion, and movement. For example, Legerstee (1991) used (i) opening and closing of a red-lined box, physically similar to mouth opening, and (ii) protrusion of a red tube from a larger, white one, physically similar to tongue protrusion; both displays contained repetitive movement. When it was found that this "alternative", non-social stimulation produced much the same effects on frequencies of infants gesturing as did the corresponding facial modelling of adults, this was rightly taken as evidence against interpretations of such behaviour as imitation. However, some authors (e.g. Lewis & Sullivan, 1985) have failed to appreciate that the negative results in such experiments were still not incompatible with contagion explanations: such results only showed that elicitation of neonatal facial gestures may be confined to social releasers (the corresponding gestures of adults).

Reports of "imitation" of facial gestures in infants usually showed it to be limited to the first few weeks, or occasionally months, of life. This is consistent with the contagion hypothesis: if neonatal matching of a few mouth movements is indeed due to innate releasing mechanisms, its later disappearance, perhaps alongside the other reflexes present at birth, would be predicted (Lewis & Sullivan, 1985).
Myowa (1996) reported "imitation" of (a human model's) mouth opening and tongue protrusion in an infant chimpanzee. In parallel to the human data, the effects were manifest only over five early weeks of this chimp's life. In line with the behavioural contagion hypothesis, yawn-like gestures are among the social "fixed action patterns" observed in primates (Provine, 1996; Visalberghi, 1997).

Implications of the present re-interpretation of the human "neonatal imitation" data are fully discussed in Chapter 4.

**Experimental Controls for Behavioural Contagion**

Zentall (1996) suggested that the best way to control for contagion and observational conditioning effects is to restrict modelling to novel or fairly infrequent actions.

The most satisfying way of determining novelty with respect to these non-imitative processes would be to map the ranges of social "fixed action patterns" for each species of interest, including humans. In doing so, it should be kept in mind that the stimuli and actions could change during development (Provine, 1996).

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2 This report suffered from a multitude of procedural errors, common to the human neonatal data (see Chapter 4); its validity is questionable.
At the very least, in the absence of such detailed knowledge, imitation tests should include modelling of a broad range of behaviours that are within an organism's competencies. This would make it less likely that elicitation alone could account for all of the observed matching (Meltzoff & Moore, 1989). Hogan (1988) suggested that deferring the opportunities for imitation may be another means of control, because elicitation would not be expected to occur in the absence of releasing stimuli. However, determining what kind of delays, if any, can be "bridged" by observers, remains an empirical issue.

**Social Facilitation (Enhancement)**

The term social facilitation (enhancement) has been used to describe a broad set of observations which showed that animals often behave differently in the presence of their conspecifics. Overall, animals' activity levels were usually found to be higher in social situations (Epstein, 1984). The explanations offered for this effect were usually vague and varied from "energising" of already strong responses, to fear and drive reduction, or to increase in the likelihood of emitting previously weak responses, all attributed to the presence of others (Galef, 1988), or perhaps to the presence of active others, whose actions may or may not have been reinforced (Zentall, 1996).

Almost all discussions of social learning in animals refer to social facilitation (enhancement). These terms are used loosely, to describe the immediate, ongoing effects of the other's presence in situations in which target responses could be emitted simultaneously with those of the
model, and the delayed effects of the other's presence on later, solitary performances. In many of these discussions, it is unclear how social facilitation (enhancement) effects could be differentiated from behavioural contagion and observational conditioning (see previous heading), local and stimulus enhancement (see next heading), and emulation processes (see later headings).

Using a single, blanket term to describe all of the possible social influences on the performance of any animal species seems unwarranted. Trying to label the broad range of differences in the behaviour of human infants in social and non-social situations as social facilitation (enhancement) would certainly be too simplistic. However, discussions of social facilitation (enhancement) have served as a reminder that the mere presence of (active) others can be functional in affecting an organism's performance.

Meltzoff (1995) reported selective matching in infants who observed adult human, but not machine, modelling of a pulling-apart target action. He defended his findings against re-interpretation in terms of social facilitation by reporting no overt differences in the infants' attentiveness, fear, and social referencing directed to parents, between the two types of demonstration (human vs. machine). However, not all investigators were as mindful of these effects. For example, Heyes (1993) reported that rats selectively matched the direction of joystick movement after the conspecifics' modelling, but not after automated movement demonstrations; she provided no comment regarding the possible
differences in the observers' behaviour during the two types of demonstration.³

**Experimental Controls for Social Facilitation**

It is not normally possible to separate social facilitation and imitation effects, because imitation occurs in social settings. In order for imitation to be demonstrated, the effects of modelling must be shown to be over and above any facilitation of the observer's responding that is obtained in the presence of an active other who is not modelling the target actions. The types of activity that should be used are constrained by consideration of other non-imitative learning processes, described in the following paragraphs.

**Stimulus and Local Enhancement**

It has often been suggested that a model's actions may serve to draw an observer's attention to a place where the activity is being carried out, as well as to an object, and part(s) of an object which are being acted upon (Custance, Whiten, & Fredman, 1999), especially if the model's actions are seen to produce some visible reinforcement.

³ The rat "imitation" data from this lab turned out to be due to olfactory cues left on the equipment by the modelling rats (Heyes, 1999).
Spence (1937, cited in Miller & Dollard, 1941) was the first to use the term *stimulus enhancement* to describe how movement of parts of apparatus by the model ("leader"), coupled with the appearance of food (reinforcement), may enhance the stimulus value of a part of the apparatus, thus making the observer more likely to respond. Hayes (1994) proposed that stimulus enhancement ought to be regarded as a subset of single stimulus learning, as defined and studied in contemporary learning theory with respect to asocial learning phenomena.

Stimulus enhancement has been said to promote the exploitation of novel food sources in kittens (Wyrvicka, 1988; but see Leyhausen, 1998), juvenile monkeys (Fragaszy & Visalberghi, 1996), and rats (Galef, 1996; Tuci, Noble, & Todd, 1999). Examples not concerned with feeding included: (i) selective playful stone manipulation in monkeys, who sought and preferred the stones that were previously handled by others (Huffman, 1996), (ii) immediate and deferred increases in pecking and pulling in pigeons who observed these actions being performed by other pigeons (Epstein, 1984), and (iii) in octopuses, the selective attack on coloured balls that were seen to be attacked by other octopuses (Fiorito & Scotto, 1992).

In a particularly good series of experiments with capuchin monkeys, Visalberghi (1993, 1997) recorded monkeys’ looking times at the apparatus that was used by a human model. The capuchins looked more when the model was near the apparatus, and showed more interest in the task afterwards, thus demonstrating stimulus enhancement effects—even though they were unable to profit from the modelling itself and solve the
instrumental problem.

Overall, effects that have been classified under the labels of stimulus and local enhancement could be explained in several different ways, by considering both the types of actions that were observed and the environmental contexts in which learning occurred (Howard & Keenan, 1993; and see Galef, 1988). The comments made about social enhancement also apply to these terms, which are too general to provide a satisfactory account of the performances of any species, but can be useful as a reminder against over-interpretation of findings, and for highlighting plausible functional relationships that may be worthy of study in their own right.

Surprisingly, studies (or even discussions) of stimulus enhancement in human infants are difficult to find, although most parents and developmental researchers would (informally) agree that, in situations where toys abound, those manipulated by others seem to hold a special appeal for most babies. These omissions are noteworthy because recent comparative data indicate that the effects of observing others' manipulation may be stronger and more specific than previously suspected. Caldwell, Whiten, and Morris (1999) reported that, in addition to the general increase in attention to the task due to modelling, marmoset monkeys preferentially handled the specific parts of an artificial fruit apparatus that were handled by a (human) model.
Experimental Controls for Stimulus and Local Enhancement

In order to separate the effects of stimulus and local enhancement from the imitation of actions that involve object manipulation, it is necessary to introduce a control in which the observers are exposed to a model acting on the same object (location, part of the environment) without performing the target actions. Once again, not just any alternative action can be used if controls for other non-imitative learning mechanisms are taken into account (cf. Meltzoff, 1988, 1996).

Alternatively, modelling of gestures that are performed without objects automatically controls for these effects (Zentall, 1988), as does the use of novel arbitrary actions (that are unlikely to be spontaneously emitted under any circumstances) on objects with no constraining affordances (that cannot support individual learning of the target actions; see the next heading).

Apparent Matching: Individual Learning, Environmental Constraints, and Object Affordances

Apparent matching can occur when two or more individuals are, either simultaneously or sequentially, exposed to identical environmental stimulation, which may shape, evoke, or even elicit uniform responding. The behaviours that develop in such situations may be very complex indeed, but uniformity within a group cannot, by itself, be taken as evidence for social learning of any kind, much less for imitation (see
Many observational studies have described and analysed tool use, feeding patterns, food processing methods, gestures used in social contexts, and other "behavioural traditions" within and between different animal populations, most notably primates (see Tomasello, 1990, 1996, and Visalberghi & Fragaszy, 1990, for excellent critical reviews of the ape and monkey data, respectively).

Most primate researchers have favoured the "richest" explanations in terms of spontaneous imitation; these were supposedly supported by indirect evidence, such as the quality of behavioural matching, the invariance of action sequences, or the acquisition speed and spread within a population (Byrne & Russon, 1998; Lefebre, 1995; Russon, 1996). By contrast, those researchers who opted for direct longitudinal observation of the acquisition processes were more cautious in their interpretations (Huffman, 1996; Inoue-Nakamura & Matsuzawa, 1997).

For example: Some of the strongest claims for imitation in non-humans were recently made, for a group of rehabilitant orangutans in a Borneo camp, where several animals, who had extensive but unknown histories of training and interactions with humans in captivity, were observed to perform fairly long sequences of human-like actions on objects, such as fuel siphoning, fire-making, weeding, canoeing, and painting (Byrne & Russon, 1998; Russon, 1996; Russon & Galdikas, 1993, 1995). The authors were impressed by the complexity of orangutans' actions, which were clearly
outside the repertoires of animals living in the wild. However, non-imitative learning processes, as well as life-long human cueing, shaping, and (un)intentional reinforcement would have been expected to promote the acquisition of complex object manipulations (and see the following headings).

Bauer (1998) has argued that the complexity of actions cannot, in itself, be taken as evidence of imitative learning. She asserted that it is the appearance of acts that are arbitrary for a given species that indicates that imitation was involved in their acquisition. This is not so: in order to claim that certain actions could not be learned individually, one must start by demonstrating that exposure to human tools alone would not result in comparably skillful performances. Indeed, it has often been reported that primates learned to perform many "conventional" actions on objects with no tuition or human help of any kind, save for shaping by the "built-in" constraints of the objects' affordances (Gibson, 1990; Tomasello, 1990; Tomasello, Davis-Dasilva, Camak, & Bard, 1987). In a similar fashion, the constraints on manipulation which undoubtedly operate in the natural environment of primates "conspire" against variability between individuals' performances of important behaviours, such as complex foraging techniques (Bauer, 1998; Vereijken & Whiting, 1998; Whiten, 1999).
Experimental Controls for Apparent Matching, Individual Learning, Environmental Constraints, and Object Affordances

The first step towards control for apparent matching which is due to the constraints of objects and the environment, is to recognise that behavioural uniformity and complexity are the expected outcomes of individual learning in many contexts (Matheson & Fragaszy, 1998; Miller & Dollard, 1941). It then follows that a large collection of arguments within the human-developmental (e.g. Oliphant, 1999; Skoyles, 1999; Tomasello & Camaioni, 1997; Tomasello, Kruger, & Ratner, 1993) and other animal-comparative literature (e.g. Wyrwicka, 1988), that have assumed that imitation is necessary to account for such outcomes, carry very little weight (Bauer, 1998; Hayne, 1998).

Secondly, many have argued that observational reports alone cannot provide conclusive evidence for any learning process, including imitation (see Byrne & Russon, 1998, and the commentaries on this article).\textsuperscript{4} Even in carefully executed experimental studies many alternative accounts of matching remained plausible (Huffman, 1996; and see Chapter 4); in

\textsuperscript{4} The most reliable way to control and manipulate the variables of interest is to perform experimental tests. However, many have argued that the observational data should be utilised in designing these tests in order to re-create as much as possible of the contexts in which the behaviours of interest are said to appear, and thus to avoid the situations that may be "unnatural" for the participants (Zentall, 1988, Whiten, 1999).
most cases multiple learning mechanisms would have been expected to operate together. Extreme caution should always be exercised in interpreting experimental data with participants whose learning histories are not known or cannot be controlled, such as the "enculturated" primates and human children.

Unless studied as a phenomenon of interest in its own right (e.g. controlled and manipulated as one of the variables that may be functional in imitation), modelling of conventional actions, which could be already known to the observers or readily learned within the experiment through the exploration of objects with constraining affordances, should be avoided.

Indeed, several researchers have suggested that only selective matching of arbitrary actions could present strong evidence for imitation. However, this is so only if the arbitrariness of the actions is defined with respect to the objects on which they are performed. By contrast, Bauer (1998) was clearly mistaken in judging the arbitrariness of the actions in terms of their goals. While the human goals of "fire-making" or "cleanliness" may be foreign to an ape, the actions of pouring gasoline into a cup and washing with soap are far from arbitrary in environments where canisters, cups, bars of soap, and water are placed together and readily available (Russon, 1996; Visalberghi, 1999).

Modelling of actions that are arbitrary with respect to the objects on which they are performed has certainly not been a common practice in the published studies with human infants. The action-object pairings in these studies included dangling of suspended toys, pushing of buttons, filling of
cups, and opening of hinged wooden blocks (e.g. Hart & Fegley, 1994; Meltzoff, 1985). The non-arbitrary action-object pairings employed in these studies would have supported apparent matching in at least two ways: (i) by the generalisation of similar known target actions on similar conventional objects, and (ii) by on-line, individual learning of target actions through the consequences of object manipulations (object affordances). Thus:

1. Although the authors have often claimed that test objects were novel—either because they were constructed in the laboratory (Meltzoff, 1988c), or because they could not be found in the infant participants' homes—the generalisation of existing repertoires of conventional behaviours with perceptually similar toys would certainly be expected in such tests (Barnat, Klein, & Meltzoff, 1996; Killen & Uzgiris, 1981).

2. Target objects' affordances were so constraining that virtually no actions, save for the target ones, could be performed on them. In a few of these experiments, alternative, non-target actions were modelled as a control for stimulus enhancement (see earlier headings and further discussion in Chapter 4): these alternative actions had to be performed on the modified object assemblies, while the original ones were used in the testing (Abravanel, 1991; Meltzoff, 1988b, 1988c). 5

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5 For example: one target object consisted of two flat wooden pieces that were joined by a hinge. The corresponding target action consisted in pushing one of the pieces to “close” it down onto the other piece (as if closing a book). The corresponding alternative action was sliding one piece over the other; this could only be performed when the hinge between the
Many comparative authors have argued that a good control for apparent matching, as well as for some of the other non-imitative learning mechanisms, is the assessment of matching of two or more alternative actions that are modelled on the same object or apparatus, which is designed to afford all of the alternative actions. Variations of this paradigm were used in: (i) two-action studies with budgerigars, pigeons, and quail (Aikins & Zentall, 1996; Dawson & Foss, 1965; Galef, Manzig, & Field, 1986; Zentall, Sutton, & Sherburne, 1996), (ii) the bi-directional control procedure with rats of Heyes and colleagues (Heyes, 1996a, 1996b, 1999; Heyes & Dawson, 1990; Heyes, Dawson, & Nokes, 1992; Heyes, Jaldow, Nokes, & Dawson, 1994), and (iii) the artificial fruit processing studies of Whiten and colleagues, with monkeys, chimpanzees, and human children (Caldwell, Whiten, & Morris, 1999; Custance, Whiten, & Fredman, 1999; Whiten, 1998, 1999; Whiten & Custance, 1996; Whiten, Custance, Gomez, Texidor, & Bard, 1996).

The shortcomings of some of these experiments are discussed in the following chapters; the important point to be made here is that the participants' performances of all alternative actions were scored and analysed. This control differs markedly from those usually employed with human infants, where only a single action was designed and scored as the target for each object-action pair (e.g. Hanna & Meltzoff, 1993; Heinmann & Meltzoff, 1996; Barnat, Klein, & Meltzoff, 1996). Meltzoff (1996) asserted that the "cross-target" procedure used in the neonatal imitation studies, wooden pieces was removed. In testing, all infants were presented with the hinged object, on which the alternative, sliding action could not be performed.
where a single adult model performs several different facial gestures (e.g. Meltzoff & Moore, 1977, 1983), should be considered equivalent to the two-action method; therefore it can be used to distinguish between imitation and other forms of social learning.  

To summarise.

In order to control for apparent matching due to generalisation of known responses to objects, the participants' existing behavioural repertoires ought to be assessed in as much detail as possible (and see the discussions of response facilitation and novelty). For example, this could be accomplished through surveying observational and other relevant data for the target species, group, or developmental level, as well as by recording individual participants' baseline performances prior to modelling (Hayne, 1998). Very brief measures of baseline behaviours should not be considered sufficient for the assessment of novelty.

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6 While this is true, Meltzoff's argument appears to be intentionally misleading in suggesting that *all* of the infant imitation studies from his lab were as well controlled as the most recent comparative ones, which was clearly not the case. In fact, he often argued for one-action-per-model as a procedure of choice for the early facial gesture imitation studies; further, two-action procedures were never used in his object-manipulation experiments with older infants (and see further critique in Chapter 4).

7 Charman and Huang (1999 and 2002; and see Chapter 4) argued that "baseline" behaviours (in the sense of being recorded in conditions other than in response to modelling of target behaviours) may themselves be influenced by a range of contextual variables and non-imitative social influences, provide misleading information about
Controls for on-line individual learning through objects' affordances ought to include multiple, novel target actions that are arbitrarily paired with objects which do not contain constraining affordances.

Finally, modelling of gestures, providing that these are novel for the participants, is probably the best way of eliminating apparent matching from an imitation experiment.

**Emulation**

*Emulation* is a fashionable cognitivist label given to much the same effects that were previously classified as social facilitation and stimulus enhancement (e.g. Tomasello, 1996 and 1998; see earlier headings). Emulation has been broadly defined as learning about the relevant aspects of the environment through observing the (results of) activity of others. According to Byrne (1993), emulation labels a special case of learning the correlational structure of the environment via classical conditioning.

Many results from recent primate imitation experiments have been interpreted as emulation. In a much cited study, Tomasello and colleagues used an adult chimpanzee, who "devised" his own strategies for raking food with a T-bar, as a model for a group of young chimps. The observers differed from a group not exposed to modelling by quickly learning to use the participants' competencies, and lead to incorrect inferences about the effects of modelling.
the (relatively novel) tool, although the control animals showed as much interest in the task and manipulated the bar extensively. The authors concluded that the observer chimps learned—via emulation—something about the affordances of the bar, its relationship with food, or the causal relationship between movement of the bar and the food. Imitation was ruled out because the observers used idiosyncratic raking strategies, rather than reproducing those employed by the model (Tomasello, Davis-Dasilva, Camak, & Bard, 1987). These results were replicated in a later study, where performances of chimpanzees and two-year old children were directly compared within a two-action task, with human models demonstrating alternative instrumental responses (Nagell, Olguin, & Tomasello, 1993). While human children selectively employed the observed strategies, even if those were less successful than the alternatives in retrieving a (putative) reinforcer, the chimps' performances were on the whole successful in obtaining the food, but insensitive to the precise behavioural details of the alternative methods observed.\footnote{The human data presented in this study can be criticised on various grounds: (i) instructions were used by the experimenters in order to establish turn-taking, and (ii) parents were present to "guide" the infants' actions by verbal instructions and prompts, in order to 'encourage' them to retrieve toys. The likely effects of parental shaping of target responses were indicated by the children's "growing tendency to imitate", recorded as the trials progressed.} Further, Call and Tomasello (1994) reported that emulation and much trial-and-error learning, but no imitation of the strategy observed, were shown by their orangutan participants who were exposed to either human or trained conspecific's modelling.
As is the case with all the labels that have appeared in the discussions of social learning, there have been several different ways in which the term emulation was used, and much talk about how it ought to be used in the future (see Call, 1999). At least four different meanings of the term can be extracted from the recent literature (see Custance, Whiten, & Fredman, 1999); these four putative social learning mechanisms are discussed next.

**Emulation as Goal Enhancement**

Whenever a model's actions are reinforced in some way, the observer's attention may be drawn to the reinforcer and to the object or tool that was used to produce it; the ensuing manipulation can be interpreted as an attempt to obtain reinforcement. In other words, the observer would be expected to engage with the relevant aspects of the environment more readily and persistently after the exposure to reinforced modelling.

Authors with a more cognitive approach have suggested that seeing others' actions may lead to adopting others' goals, and then to attempting to attain these goals by devising one's own methods and working out what actions to use (Tomasello, 1990; Whiten & Ham, 1992). However, others have argued that inferring others' goals and intentions would be a difficult thing to do for participants (Call, 1999), and for the experimenters to justify (Whiten, 1999; also see discussion of goal-directedness in Chapters 1 and 8).

It remains an empirical question whether there is something specially "social" in all such contexts: seeing a reinforcer in the presence of an
object or tool may result in establishing the latter either as a classically conditioned reinforcer, or as a discriminative stimulus for approach and manipulation (Hogan, 1988, after Miller & Dollard, 1941, referred to this effect as "stimulus valence transformation"). Such learning may be promoted by the presence of an active model (see previous headings).

It should also be noted that a model's actions may only exceptionally produce "visible" reinforcers such as food or toys (e.g. Tomasello, Kruger, & Ratner, 1993), while object handling (play, exploration) may be reinforcing in its own right for many species. In the latter contexts, goal enhancement would presumably be indistinguishable from stimulus enhancement (see previous headings).

Experimental Controls for Goal Enhancement

In many imitation studies with human infants, the modelling of target actions often provided immediate and obvious consequences that could have been reinforcing for the participants, such as interesting object transformations, light, and sound. Meltzoff (1985, 1988, 1996) acknowledged the possibility that infants may attempt to obtain the same consequences when given the chance to manipulate the objects. He argued that goal enhancement was controlled for because identical consequences were produced by the "control" actions as well. This was not so, because children's attempts to obtain the reinforcing consequences would, through differential affordances of the target objects, lead to correct matching of the (afforded) target actions and not to matching of (unafforded) control actions (see previous heading).
It has been suggested that only selective and fairly precise matching of observed actions within a multiple-action procedure (Custance, Whiten, & Fredman, 1999; Whiten 1999) should be accepted as evidence that mechanisms more complex than goal enhancement were operating in a learning episode. Indeed, goal enhancement cannot result in: (i) selective matching of novel, arbitrary actions on objects without differential affordances, and (ii) selective matching of gestures.

**Emulation as Affordance Learning**

An observer could learn about the types of action that an unfamiliar object or a tool affords by observing a model's manipulations. Thus an observer could learn that a target object—a novel jar or a box for example—affords opening (Tomasello, Kruger, & Ratner, 1993). The benefits of this putative learning mechanism would necessarily depend on the observer's knowledge of object manipulation and transformation (Call, 1999).

For example: Fritz and Kotrschal (1999) reported that only ravens who observed a trained conspecific pulling a ribbon, attached to a food container lid, later exhibited the opening by pulling themselves. One could say that seeing that the ribbon affords pulling, a common behaviour in these birds, rather than direct contact with the object's affordances, influenced the participants' performances. However, it is not clear how this effect could be differentiated from stimulus enhancement (the ravens observed a conspecific touching the ribbon) or object movement re-enactment (see the next heading). The same applies to the experiments of tool use in apes and human children described earlier (Call & Tomasello,
1994; Nagell, Olguin, & Tomasello, 1993; Tomasello, Davis-Dasilva, Camak, & Bard, 1987), where participants were said to have learned that a T-bar affords raking, or about its function as a tool.

While it remains open to debate whether talking about affordance learning makes any useful distinctions, as compared to the other putative emulation mechanisms, some authors have already adopted the use of this term as a shorthand in discussing the results of the experiments with human infants. Charman and Huang (1999) criticised a much publicised claim that infants can imitate failed attempts at actions, usually interpreted in terms of early theory of mind abilities (Meltzoff, 1995). They noted that the "failed" modelling attempts in Meltzoff's study presented the infants with the affordance demonstrations, but the "alternative" control actions did not. Thus it may have been affordance learning—and not imitation of mind-read intentions of adult models—that led infants to pull the target objects apart after seeing the "failed" modelling of pulling, but not after seeing the "control" actions.

It has been suggested that the ability to profit from affordance demonstrations, perhaps more than is the case with the other emulation mechanisms, depends on complex cognitive capacities for recognition and learning about the relational characteristics and structure of the environment (Call, 1999; Russon, Mitchell, Lefebre, & Abravanel, 1988). These phenomena are certainly worthy of study themselves (as is the case with all social learning mechanisms, see Visalberghi, 1999), not least because learning about the environment may be no less complex than learning about behaviour, or imitation (Roitblatt, 1988; Tomasello,
Experimental Controls for Affordance Learning

Controls that can distinguish between imitation and affordance learning include the use of multiple, novel, arbitrary target actions, and the modelling of (novel) gestures, without objects. Studies that incorporated the use of multiple-task controls (although not necessarily with entirely novel actions) have so far been reported with monkeys, chimpanzees, and human children (Tomasello, Savage-Rumbaugh, & Kruger, 1993; Whiten & Custance, 1996).

Emulation as Object Movement Reenactment

An individual could learn, through observation of a model's manipulations, how an object or its parts move. If this object-movement had consistently been associated with a reinforcer, the observer may attempt to effect the same object-movement. Once again, classical conditioning of a sort is assumed to promote the observer's learning (Tomasello, 1990).

Much of the comparative data on "imitation" can be reinterpreted in terms of movement reenactment, although it is often impossible to say whether the effects were in fact due to the simpler process of stimulus enhancement coupled with individual learning. As mentioned earlier, budgerigars, pigeons, and quail were all reported to prefer using one of two or three
different methods for removing a food-dish cover after observing the appropriate demonstrations (Dawson & Foss, 1965; Galef, Manzig, & Field, 1986). Very fine differences in movement could have been used by pigeons, who selectively matched the modelled actions of stepping versus pecking on a treadle (Zentall, Sutton, & Sherburne, 1996).

Once again, this type of learning does not seem to be restricted to social contexts. It has been reported that rats immediately moved a lever in the appropriate direction after exposure to the multiple pairings of automated movement with the presentation of food (Denny, Clos, & Bell, 1988, but see Heyes, 1999).

Many authors have argued that object movement reenactment should be understood as a complex skill that can produce impressive learning results, such as selective action matching in capuchin monkeys who observed alternative models in an artificial fruit processing task (Custance, Whiten, & Fredman, 1999). In other words, not all species would be expected to show the ability to learn in this manner. Call and Tomasello (1990) reported that three and four year old human children, but not orangutan participants, were able to utilise movement cues to obtain sweets.

Whiten and Ham (1992) have argued that the distinction between object movement reenactment and imitation is not clear cut. As noted by Whiten and Custance (1996), hammering may be thought of as extended limb action, and conversely limbs can be seen as very intimate "tools". Thus seeing and reproducing the movements of objects may in fact be similar to seeing and reproducing the movements of others' limbs holding objects, or
even simply gesturing; different skills and mechanisms may or may not be involved as far as the participants are concerned. This is compatible with the behaviour analytic view of imitation (see Chapter 3), which emphasizes visual matching of own and others' behaviour that can, in principle, extend to movements of objects and not just of body parts; the notion is incompatible with the nativist developmental theories of imitation (see Chapter 4), which assign a special role to cross-modal mapping of organ-organ, body relations.

Experimental Controls for Object Movement Reenactment

Most actions on objects produce movement as a consequence, and it may be difficult to defend the imitation claims against this alternative whenever objects or tools are used for modelling (Custance, Whiten, & Fredman, 1999). While it may be possible to design object-action pairs that produce identical movements in more than one way, such target actions may be too precise and exceed participants' motor competencies (Whiten, 1999).

Once again, the use of novel gestures, with no objects, would rule out object movement reenactment as a possible cause of selective matching.

Emulation as Final State Re-Creation

It has been suggested that an observer may see the final state or result of a model's manipulations, possibly associated with reinforcing consequences of some sort, and then attempt to re-create the result when presented with
the same or similar objects later on (Custance, Whiten, & Fredman, 1999). As in the other emulation variants, it is not the models' actions that influence the observers, who instead rely on previous experience and individual learning. The term is presently fairly loosely defined and some authors have stretched the meaning of final state re-creation to include mimicking of songs in parrots (Byrne & Russon, 1998, but see Moore, 1992, 1996).

It had been said that this type of learning may have been responsible for the findings that marmosets were likely to match the observed strategies of door pulling, holding, or pushing to obtain food (Buganyar & Huber, 1997), and that young hamsters matched their mothers' methods of food retrieval by pulling or holding on to chains (Prato-Previde & Poli, 1996), although alternative explanations in terms of stimulus enhancement and object movement reenactment could be given as well.

While it has been claimed that many animal species could re-create final states of object transformations without observing the actions that achieved them, it has been reported that only toddlers, and not infants, who were presented with initial object states and then with the completed target transformations, were able to perform the appropriate actions, even if these were within the infants' repertoires (Charman & Huang, 1999). It seems reasonable to suggest that action complexity and the participants' knowledge of object transformations may be among the variables affecting performances on such tasks (as is the case with other emulation processes, see earlier headings).
**Experimental Controls for Final State Re-Creation**

Suggested ways of controlling for this non-imitative matching mechanism include: (i) modelling of unfamiliar object manipulations with either non-transparent solutions or no object transformations, (ii) restricting the test duration in order to minimise the possibility of apparent matching and individual on-line learning (Charman, 1999), (iii) the use of multiple-action procedures which produce the same end-results (Heyes, 1999), as well as (iv) modelling of gestures in the absence of objects.

**Response Facilitation**

It has been suggested that exposure to modelling of the actions already in an observer's repertoire may temporarily increase the probability that the observer would emit (reproduce) these actions (e.g. Byrne, 1994; Byrne & Tomasello, 1995). This putative social phenomenon differs from all of the others discussed in this section, because a model's actions are expected to determine (influence) an observer's behaviour directly, as opposed to indirectly, through mere presence or the effects on the environment. It has been suggested that response facilitation should be seen as a form of *priming* (see Byrne & Russon, 1998, and the commentaries on this article), which is a descriptive term borrowed from the cognitive literature, usually referring to memory, social cognition, and linguistic phenomena, presently not researched in species other than humans (Chartland, Lee-Chai, & Bargh, 1998).
It is important to note that response facilitation or priming was offered as an *explanation* for behavioural matching, under the assumptions that brain records of known actions exist and that the perceptual system registers the similarity of actions performed by the self and others. Priming then means the activation of the corresponding action record by observation (Byrne & Russon, 1998). These assumptions are hotly debated topics in their own right. As noted by Zentall (1998), such an "explanation" of behavioural matching itself depends on specifying the nature of these representational structures, and finding out about how they are formed.

Many have questioned the utility of this label on the grounds that it implies that behavioural novelty and familiarity can be defined in absolute terms (Whiten, 1999; and see Chapter 1). It has also been suggested that the cognitive mechanisms underlying response facilitation would have to be as complex as, and possibly no different from, those responsible for imitation (Schaal, 1999). Both of these points will be discussed in more detail in Chapter 3.

Whatever the final verdict may turn out to be, the term response facilitation has been widely used to dismiss reports of imitation in just about every species tested so far, especially rodents and birds (Byrne & Tomasello, 1995). Some ethologists distinguished "true" imitation of novel acts from matching of known behaviours that are said to be "inspired" by modelling (e.g. Russon, 1996). Possible evidence for this phenomenon was presented by Epstein (1984) who briefly reported that when a novel action was trained and then extinguished in pigeons, it would reappear after
modelling. However, simpler explanations may be possible if objects were involved, a point that was left unclear in the original article.

It needs to be noted that the present distinction calls for the relabelling of almost all of the human developmental data, where entirely novel actions were seldom, if ever, modelled (Byrne & Russon, 1998; Heyes, 1998; Meltzoff, 1988b).

**Experimental Controls for Response Facilitation**

As discussed in Chapter 1 and in the earlier headings in the present chapter, the novelty of target actions ought to be determined in all tests of imitation. The distinction between known, well-practiced responses and those that are not as yet a part of an organism's repertoire is an important one. Strong claims for the learning of conventional behaviours through imitation, made for human infants and children, can only be supported by data that show their matching of novel behaviours, without direct training (generative imitation).

Thus, experimenters need to familiarise themselves with the behavioural repertoires and the learning histories of their individual participants in order to determine the appropriate, novel target actions in imitation tests (see further discussion in Chapters 3 and 5).
Trained (Operant) Matching: Matched Dependent Behaviour, Cueing, and Shaping

Shaping and contingent reinforcement can establish the specific acts of others as discriminative stimuli for the performance of perceptually similar responses. This is referred to as trained (operant) matching. Shaping and reinforcement for matching can be provided either through deliberate training, or "by chance" in a variety of different environments. Miller and Dollard (1941) were the first to describe trained matching; they used the term "matched dependent behaviour" and presented an extensive discussion, some relevant data, and a list of plausible examples (also see Skinner, 1953, 1957).

Trained matching, like other operant responding, would necessarily remain restricted to a finite set of (trained, discriminative) actions, although some generalisation of responding to perceptually similar cues would be expected (Zentall, 1998). Once again, it needs to be noted that there may not be anything specifically social about this type of learning. A wide range of non-social stimuli can become established as discriminative stimuli for various actions, and it remains an open empirical question whether operant learning (of matching) may be facilitated by the use of social stimuli (modelled behaviours), which are perhaps more attention-getting in certain settings.

There have been surprisingly few references to trained (operant) matching as a possible alternative interpretation of the "imitation" findings in the social learning literature (but see Gardener, 1999; Heyes,
1998, 1999), save for a few citations of early experiments involving simple following behaviour in rats and children (Miller & Dollard, 1941). The omissions are especially important in studies of primates, where trained (operant) matching could have served to produce apparent imitation both directly and indirectly. First, it is quite likely that many of the ape participants, who were veterans of intensive training programmes (e.g. language, cognition), came to the “imitation” tests equipped with substantial—but uncharted—repertoires of trained matches. Through generalisation, these apes would have been expected to emit the previously trained matching responses to perceptually similar modelled gestures or actions (Heyes, 1998). Second, the human models could have further influenced the observing apes' approximate performances through inadvertent on-line shaping and cueing (e.g. Bard, 1988; Hayes & Hayes, 1952).

For example, Carpenter, Tomasello, and Savage-Rumbaugh (1995) reported that advanced joint attention skills in “enculturated” chimpanzees may have been a prerequisite for imitation, which was not obtained with apes who had not had the experiences of tutoring and interactions with humans. Indeed, they reported that the chimps' “imitation” episodes involved looking at objects during demonstrations, but glancing at human experimenters while performing. It is therefore possible that successful “imitation” of target actions was due to generalisation of trained (operant) matching and emulation, supplemented by social shaping and cueing, to which these “enculturated” animals were likely sensitive. The effects of on-line shaping and cueing of correct matching performances were also likely present in studies where
"imitation" was said to have been established only through several rounds of modelling and responding (Whiten, 1998, 1999).

One study of action repetition in dolphins presented a rare positive example of its authors' awareness of the role that cueing and on-line shaping can have on "enculturated" participants' correct matching performances (Mercado, Murray, Uyeyama, Pack, & Herman, 1998). Mercado and colleagues' dolphin participants had undergone extensive training by humans and were therefore assumed to be responsive to subtle human cueing; in order to control for this, the trainer giving the action commands was ignorant of task order and was wearing opaque goggles.

Naturally, cueing and on-line shaping would have been expected to be even more effective in experiments with human infants, where several adults (usually parents, experimenters who acted as models, and coders or assistants) were often present in all of the conditions. However, developmental publications seldom mentioned the possibility of inadvertent on-line shaping of target responses in experimental contexts; consequently, adults' actions were not controlled or recorded (e.g. Nagell, Olguin, & Tomasello, 1993; Meltzoff & Moore, 1994; but see Meltzoff, 1996).

The possibility that trained (operant) matching, supported by children's sensitivity to social consequences, could be responsible for infants' "imitative" actions and gestures, has seldom been contemplated by developmental theorists. For example, Tomasello, Kruger, and Ratner (1993) asserted that imitation is the only way to learn the appropriate use of conventional symbols, because it is unlikely that infants could
spontaneously discover the conventional, arbitrary connection between sounds and referents. A similar argument has been put forward by Tomasello and Camaioni (1997), with respect to children’s use of conventional and nominal referential gestures (such as waving “bye-bye” and driving motions for “car”). In these two arguments, not unusually, imitation was evoked to explain learning because the alternatives that the authors could think of seemed implausible to them. What is remarkable in the present two examples—and unfortunately quite typical of other developmental writing—is that social teaching and shaping, including trained matching, were not even considered as possibilities. Such lack of appreciation is puzzling, not least because several recent and well-known studies with monkeys, apes, dolphins, and human infants have actually used direct (operant) matching training (of a range of behaviours) prior to testing imitation of novel actions or gestures (e.g. Custance, Whiten, & Bard, 1995; Fragaszy, 1997; Herman, 1999; Poulson, 1999).

Most surprisingly, no controls for either trained (operant) matching or for on-line shaping and cueing were employed in behaviour analytic infant studies (e.g. Poulson, Kymissis, Reeve, Andreatos, & Reeve, 1991), although authors working within an operant learning perspective ought to have been comparably more familiar with these concepts. The appropriate controls were absent even when the authors explicitly discussed and excluded trained (operant) matching from their definitions of imitation.

9 Tomasello and colleagues went on to add how learning by means of stimulus enhancement and emulation is impossible with such (vocal) gestures, and hence no controls are necessary in imitation tests.
(e.g. Poulson & Kymissis, 1988; also see Chapter 3 for a critique of behavioural analytic data).

**Experimental Controls for Trained (Operant) Matching**

In order to design experiments that could separate the effects of generalisation of previously trained (operant) matching from imitation, researchers could start by acknowledging that most of the "enculturated" participants ought to be assumed to possess repertoires of actions or gestures that had been trained as matches (cf. Tomasello, Kruger, & Ratner, 1993a, 1993b). This naturally includes human infants (Meltzoff, 1996). The more cautious among the theorists have suggested that all social organisms engage in synchronised reinforced behaviours (e.g. feeding), which could in principle lead to some operant matching learning, even in the absence of human interventions (Galef, 1988; Miller & Dollard, 1941; Skinner, 1953).

Overall, multiple-action procedures that consist of modelling of infrequent, complex, and arbitrary actions and gestures, can all be used to minimise the risks of misinterpretation. However, with participants who have extensive, but unknown, histories of reinforcement for matching, none of these procedures can entirely eliminate the possibility of misinterpreting some trained (operant) matching as imitation. However, the chances of demonstrating imitation increase if the following are found to be true:

1. Participants can match a very wide range of behaviours that are within their motor competencies. This is because, in very large sets,
there are more chances that at least some of the target behaviours have
not been trained as matches and are truly novel for the participants.
However, most "imitation" experiments to date employed only small
sets of target behaviours.

2. Participants' matching improves over time. This is because
generalisation of trained matching would only be expected to produce
approximate responses to novel models that physically resemble the
trained ones; imitative participants would be expected to vary their
responses in order to achieve better similarity to the modelled target
behaviour.

As discussed above, participants' matching performances would also be
expected to improve over time because of social cueing and shaping of their
responses; this can easily be misinterpreted as imitation. Therefore,
careful monitoring of the (human) models' and experimenters' behaviour
should become a standard part of all procedures. This control seems
preferable to the alternatives of restricting testing to very few trials, or
shortening the response periods, because exposure to many modelling
cycles with several response opportunities may itself be a prerequisite for
demonstrating imitation: the "goodness of fit" of a match may be achieved
gradually, on the basis of comparing one's own and other's performances
(see Miller & Dollard, 1941; Whiten, 1999).
Learning to Learn by Observation

"Many investigators have studied the capacity of animals or children to imitate; no experimenter seems to have set out deliberately to study the capacity of his subjects to learn to imitate. Systematic attempts to take account of learning have been directed only toward eliminating it from the experiment. The fact that experimenters studying imitation were interested in ruling out independent learning during the experiment, as a possible explanation of their results, seems to have prevented them from becoming interested in the possibility that imitation itself could be learned." (Miller & Dollard, 1941, pp. 318)

In recent discussions, many comparative theorists have reexamined the possibility that some kind of social training may be necessary for establishing imitation in any species. Learning first surfaced in arguments regarding "enculturation" as a possible prerequisite for imitation in primates. Tomasello (1996) asserted that apes will ape only if exposed to deliberate training by humans, and then perhaps only in some ways (mimicking of gestures, but not understanding the intentions of the person whose behaviour they copy). Enculturation was offered as a blanket term covering a range of possibly relevant social experiences, such as "socialisation of attention" (Nagell, Olguin, & Tomasello, 1993, after Vygodskii, 1978), which includes exposure to objects, reinforcement of attention to objects (Tomasello, Savage-Rumbaugh, & Kruger, 1993), and "joint attention training" (see Carpenter, Tomasello, & Savage-Rumbaugh, 1995). These accounts attempted to relate comparative findings with primates to the human developmental data, but no precise account of how training may lead to imitation was offered, save for asserting that some
form of intentional social instruction is necessary (Nagell, Olguin, & Tomasello, 1993).

In these discussions, several authors have warned against using double standards when considering imitation in human infants and non-human animals. Human imitation is assumed to be innate, spontaneous, ubiquitous, and unfolding without special training (see the Meltzoff & Moore [1999] quote in Chapter 1); imitation in other animal species is said to be difficult to establish, restricted to the few "higher" taxa, and to require extensive training (e.g. Bard, 1993; Herman, 1999; Gardener, 1999; Milkosi, 1998).

It has been proposed that imitation can develop only in the (social) environments where reinforcement for imitative behaviour is available (Tomasello, Savage-Rumbaugh, & Kruger, 1993; Whiten, 1993). For example, Whiten and Custance suggested that, "the first steps that an infant takes toward imitation may require certain rewards to be forthcoming so to advance the ability, and without these, it may atrophy" (Whiten & Custance, 1996, pp. 315). It should be noted that these arguments for learning are rather circular: some imitation is assumed to occur spontaneously, or else it could not be reinforced. The development and extension of the imitative repertoires are said to occur through scaffolding, or modelling of tasks just a little above the organism's current competencies (Custance & Bard, 1994; also see Hayes & Hayes, 1952, for an older argument linking imitative ability to prior experience and individual learning competencies). It has also been argued that humans may be special because, "adults come prepared to teach youngsters, and

Recent suggestions that imitation originates from nonimitative processes and generalisation of previously learned behaviours have also been rather vague, mostly reiterating the arguments of the early theorists such as Guillaume or Miller and Dollard (see Gardener, 1999; Mitchell, 1998; Mitchell & Anderson, 1998). The absence of detail was also notable in the more original work of Moore, who proposed an evolutionary hierarchy of learning skills leading to (anthropoid) movement imitation (B.R. Moore, 1996). 10

To summarise. Miller and Dollard's (1941) critique is as valid today as it was sixty years ago, because only a few comparative studies to date have directly explored the conditions under which imitation may be learned. 11

10 In this account, the learning skills were ordered as follows: (i) Thorndikian learning or classical conditioning, (ii) Skinnerian, operant conditioning, (iii) skill learning (involving intrinsic reinforcement), (iv) putting through (with teaching and skill learning that shapes the details later on), (v) visible imitation, and (vi) invisible imitation (dependent on mapping through exploration). Various species were said to differ in their capacities to learn through these mechanisms, with the later abilities building on the preceding ones, but it was not made clear whether the more complex learning skills are themselves acquired during ontogeny, or how this may happen (see Moore, 1996).

11 These experiments, which incorporated the 'Do-as-I-do' paradigm (after Hayes & Hayes, 1952), are discussed in the next chapter.
Even those among the contemporary researchers (Gardener, 1999; Whiten, 1999) who recognised the possibility that imitation may depend on learning, and should therefore be investigated as an acquired skill rather than the spontaneous expression of a species-specific innate capacity, remained unaware of the paradigms used by behaviour analysts, who adopted the learning perspective as a starting point in their work with human participants. This section of the literature is reviewed next.
CHAPTER 3

Generalised Imitation: A Review of the Behaviour Analytic Literature

What distinguishes the behaviour analytic approach to the study of imitation is its emphasis on the analysis and control of the environmental contingencies responsible for establishing, maintaining, and modifying imitative behaviour. Some 35 years of research data have been collected with pre-school and primary school age children; many studies employed participants from special populations. To date, infant data have been reported in only two experiments. The term generalised imitation has been widely used in discussion of the findings; its use is adopted in the present critical review (but see the later headings).

Generalised imitation has often been cited as a paradigm case of a higher-order response class (e.g. Baer & Sherman, 1990; Masia & Chase, 1997); it has been incorporated into behaviour analytic accounts of child development in general (e.g. Bijou & Baer, 1967), and of language learning in particular (e.g. Horne & Lowe, 1996, 1997, 2000). However, after the initial surge of reports in the 1960's and the 1970's, studies of this topic became scarce.
Imitation in Behaviour Analysis: Theoretical Bases

Contemporary behaviour analytic accounts of (generalised) imitation are rooted in Miller and Dollard's (1941) work and Skinner's (1953, 1957) brief theoretical analyses of motor and vocal operant matching (termed "the echoic relation").¹

Miller and Dollard (1941) considered the acquisition of trained matching (which they termed "matched dependent behaviour") to be the prerequisite of imitation (which they termed "copying"). They wrote that imitation training begins with an external critic who rewards similarity and punishes dissimilarity, and that it ends when the copier becomes able to respond independently to the cues of sameness and difference. They wrote that

¹ Mowrer's (1950 and 1960) two-factor theory of vocal imitation is another early source; however, the theory was not extended to imitation of actions and gestures. In brief: Mowrer argued that the frequent pairing of caregivers' vocalisations with primary reinforcers of food, warmth, care, and so on, establishes these auditory stimuli as secondary (conditioned) reinforcers for the infant. The infant's own vocal responses produce auditory stimuli that resemble those produced by the caregivers and so also serve as secondary reinforcers. The infant's vocal behaviour is thereby not only automatically reinforced, but also (auto)shaped so as to maximise the similarity between the caregivers' vocalisations and his or her own (and see Kymissis and Poulson, 1990, 1994).
"It seems probable that different types of imitation form a continuum ranging from pure matching dependent behaviour at one extreme to copying at the other. Between these two extremes lie responses which are chiefly dependent upon the cue produced by simulation from the model's response alone, but are also slightly dependent on the cues of sameness and difference produced by stimulation of both responses." (Miller & Dollard, 1941, pp. 160)

Skinner (see 1953, pp. 119 - 122; 1957, pp. 52 - 65) never formulated a coherent theory of imitation, probably because he considered imitation to be similar to other discriminative repertoires, such as "drawing from copy" and "singing by ear". In these examples, the discriminative stimuli are not social; in the case of behaviours that are usually termed imitative, the stimuli are social (i.e. another organism's behaviours); in all cases, the behaviours are established as the result of differential reinforcements.

Skinner proposed that all behavioural matches are discriminated operants varying in size (complexity). The first matches are set up when the target behaviour of a model (or potential discriminative stimulus) is followed, initially by chance, by a behaviour that resembles it, and reinforcement is delivered. As the frequency of the latter behaviour increases, its correspondence to the modelled behaviour can be shaped by delivering a reinforcer only when it is a good match.

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2 Skinner's accounts of motor and vocal matching (echoic behaviour) resembled Miller and Dollard's (1941) writing, although no formal acknowledgement of this source was provided.
According to Skinner, when several operant matches are established, the new matches occur more readily because

- The "ineffective" responses drop out as the result of previous contingencies. For example: during the operant training of several manual matching behaviours, such as pointing and waving, non-matching behaviours that are emitted in response to the model's manual gestures, such as turning away, grabbing an object, or producing a foot movement, are not reinforced. As a result, when a new manual gesture (e.g. forming a fist) is modelled, the manual movements, previously reinforced in similar situations, are likely to be emitted; the ineffective behaviours, such as turning away, grabbing an object, or producing a foot movement, previously unreinforced in such situations, are less likely to appear.

- Smaller response units are acquired when several composite matching behaviours that contain them are established. For example, operant matching training may be provided for "waving", "head-touching", and "nose-touching" gestures. All of these operant matching responses contain the component "lifting the hand up"; thus reinforcement for matching the component gesture was also provided in the training of the composite gestures that contain it. The component gesture may therefore be emitted as a match to the corresponding gesture of a model without further training for doing so. Skinner's assertion about the emergence of a minimal repertoire of component units that are common to several trained matching responses was not based on empirical observations, but appears to be an intriguing and testable possibility.

- New matches can be acquired quickly if they consist of combinations of the already established units. For example, operant matching training
may be provided for "waving" and for "nose-touching" gestures. Subsequently, a combination of these two gestures, "waving while touching nose" may be emitted to the corresponding gesture of a model without direct training for doing so. Skinner's proposition that novel combinations of operantly trained matches can be emitted as matches without further training is testable.

According to Skinner, operant matching repertoires consist of discrete sets of responses; these repertoires may differ widely between individuals and are dependent on their reinforcement histories. Imitative proficiency (goodness of matching) is dependent on the "grain" of these repertoires, which can range from a few distinct responses to nearly continuous fields.3

The role of similarity was deliberately deemphasized in his discussion of matching acquisition. Skinner suggested that appreciation of the similarity between one's own and others' behaviours, which could become reinforcing in its own right for a sophisticated imitator, may serve to refine and so further develop the matching repertoire. However, he emphasized that the benefits of self-correction are not different in kind from those conferred through the earlier (educational) training provided by others. Thus the notion of continuity between socially-trained matching, and later matching that involves self-correction, was strongly expressed in his account.

3 Also see Skinner's (1957, pp. 52 - 65) notion of "minimal repertoires" in his discussion of vocal responses (the echoic relation).
Experimental Studies of Imitation: Generalised Imitation

The behaviour analytic study of imitation was initiated by Baer and Sherman's (1964) serendipitous finding that 7 out of 11 pre-school children, who received verbal praise from a puppet model for matching its mouthing, nodding, and verbalisations, also persistently matched a topographically dissimilar, bar-pressing behaviour, that was frequently modelled by the puppet. Thus many children matched the puppet's bar-pressing although their bar-pressing responses were not socially reinforced in the experiment.

For four children (two in each condition, see below), the nonreinforced bar-pressing responses were found to be responsive to the manipulations applied to the other, socially reinforced matching responses. Thus: (i) in the "extinction of imitation" condition, the rates of nonreinforced bar-pressing decreased when the puppet ceased providing social reinforcement contingent on matching of the remaining modelled behaviours; the rates of bar-pressing recovered after such reinforcement was reinstated; (ii) in the "time-out from imitation" condition, the rates of nonreinforced bar-pressing decreased when the puppet ceased modelling the formerly reinforced behaviours; the rates recovered when modelling and social reinforcement of such behaviours were reinstated.

A group of responses, all of which are responsive to changes in the contingencies applied to only a subset of them, are said to form a response class (Baer and Sherman, 1990; Catania, 1984; also see Barnes-Holmes & Barnes-Holmes, 2000). Baer and Sherman (1964) concluded that, for the
children who participated in their study, their matching responses must have been established as a response class. The term generalised imitation was invented to describe the extension of behavioural matching to a variety of actions, models, and contexts, in the absence of explicit training for doing so. The use of this term highlighted the apparently untrained aspect of matching in which behaviour analysts were especially interested.

Baer and Sherman's findings have been replicated and extended as follows:

- Several studies have demonstrated that reinforcement is needed to establish or maintain matching in pre-school and school-aged children. Reinforcement did not have to be given for all matching responses; when subsets of children's matching responses received reinforcement, other matching responses were established and maintained also. Thus children emitted apparently emergent matching responses to "probe" modelling of a variety of behaviours, including hand and arm movements, leg and foot movements, entire body movements, and vocalisations (e.g. Baer, Peterson, & Sherman, 1967; Deguchi, Fujita, & Sato, 1988; Peterson, 1968; Sherman, Clark, & Kelly, 1977; Waxler & Yarrow, 1970; also see Baer and Sherman, 1990). However, not all children exhibited generalised imitation in these experiments (see Baer & Deguchi, 1985; Baer & Sherman, 1964; also see Kymissis & Poulson, 1994).

- Several studies have reported that, through training of matching of large sets of different actions, generalised imitation could be established in apparently non-imitative participants (mostly children aged 8 to 14
years) from special populations (e.g. Baer, Peterson, and Sherman, 1967; Garcia, Baer, & Firestone, 1971; Lovaas, Berberich, Perloff, & Schaeffer, 1966; Peterson, 1968).

- In normally developing children, and in children with autism, generalisation of matching to nonreinforced models was found to be restricted to subclasses of topographically similar behaviours (Garcia, Baer, & Firestone, 1971; Gena, Krantz, McClannahan, & Poulson, 1996; Sherman, Clark, & Kelly, 1977; Young, Krantz, McClannahan, & Poulson, 1994; Poulson, 1999).

Many behaviour analysts have agreed that describing generalised imitation as a higher order response class, probably comprising of several smaller classes (e.g. bounded by response topographies), was no more than describing the experimental observations regarding the role of extrinsic reinforcement in matching performances. Therefore, several procedural and functional explanations of imitation were put forward (see Baer and Deguchi, 1985). A schedule effect (matching-to-sample) account, a setting effect explanation, and a conditioned reinforcement account of generalised imitation, are discussed next.

**Generalised Imitation as Matching-to-Sample (Conditional Discrimination)**

Gewirtz (1970, 1971; also see Gewirtz and Stingle, 1968) wrote that matching responses are initially established through operant training, and maintained by intermittent reinforcement. The child is said to
acquire a "learning set" across exposure occasions; thus correct responding occurs progressively faster (see Harlow, 1959). A functional class of matching responses is formed; according to Gewirtz,

"For imitative-responding, such a class would contain topographically diverse instrumental responses all of which are matched to diverse reinforced and nonreinforced responses of demonstrator-models (or one model), and whose probabilities of occurrence vary together." (Gewirtz, 1971, pp. 281)

Further, imitative-matching phenomena can be conceptualised as conditional discriminations, analogous to matching-to-sample. Thus:

"On each trial occasion, the child's response, involving the comparison stimulus from the finite number in an array, that matches the conditional (sample) stimulus [in a matching-to-sample task], is analogous to his "selecting" from a large set of alternatives in his own repertory that response which matches the cues provided by the demonstrator-model's exemplary response [in an imitative-matching task]." (Gewirtz, 1971, pp. 288)

However, the relation of similarity is not privileged, special, or reinforcing in itself, and no intrinsic reinforcement is necessary for imitation. Matches that are never reinforced persist because of intermittent extrinsic reinforcement for the class as a whole. Finally, imitative responses are reinforced in some contexts but not others, and contextual cues come to determine when, where, what, and whom to imitate.

On the whole, this account appears disjointed and somewhat unclear in places; its main claims have not been substantiated by the available
evidence. Thus:

- As pointed out by Baer and Deguchi (1985), saying that an organism acquires a "learning set" through operant matching training is to do no more than supply a descriptive label, itself in need of explanation.

- It is said that imitative-matching is established as a functional response class through intermittent reinforcement (see Catania, 1998). Intermittent reinforcement can be invoked to explain the maintenance of already established responding within such classes; however, it cannot account for the acquisition of entirely new responses (Baer and Deguchi, 1985). Therefore, Gewirtz' account does not explain truly generative imitation (see Chapter 1).

- This explanation relies on the assumption that imitators do not discriminate between reinforced and unreinforced actions. However, Gewirtz did not specify why the participants in generalised imitation studies would be insensitive to the contingencies operating within the experimental setting, while also being extremely sensitive to those operating between settings (contextual control of when, where, whom, and what to imitate).

As Baer and Deguchi (1985) pointed out, the multiple schedules arranged in generalised imitation experiments would have been expected to promote perfect discriminations: some matches are reinforced either continuously or intermittently, while the remaining matches are never reinforced (these schedules could be described, respectively, as FR1 EXT and VR EXT
multiple schedules). 4

It has been shown that pre-school and school-age children, who were presented with a choice of modelled behaviours, or exposed to models who never reinforced matching, or asked to describe the contingencies, were always able to discriminate between the reinforced matches and nonreinforced probes, while continuing to match both under most conditions (see Baer & Deguchi, 1985; Sherman, Clark, & Kelly, 1977; Steinman, 1970). Steinman's experiment serves to illustrate this point, as well as to introduce his account of generalised imitation, presented in the next heading.

Steinman (1970) presented seven to nine year old children with modelling of various actions (mostly gestures). Two experimenters acted as models; each modelled a different set of behaviours; both asked the children to "Do as I do". The experimenters presented modelling either individually or jointly; in the latter condition children were presented with a choice of models on each trial. One of the models always reinforced correct matching (with beads); the other one never did. In the single-model trials, children matched both models; in the choice trials they matched the model who produced reinforcement. In further single trials children were instructed not to match the modelled behaviours that they do not get

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4 In an extreme example of a setting that ought to have promoted perfect discriminations, Bufford (1971) reported that continuous reinforcement for a single vocal match, presented in half of the trials, maintained one participant's matching of 10 non-reinforced vocal matches, presented in the remaining half of trials.
beads for; they complied perfectly. In the remaining single trials, children were instructed to match what they will; matching of nonreinforced probes resumed for many children.

The Setting Effects in Generalised Imitation

Steinman (1971, 1977) argued that generalised imitation is an artifact of task demands and manipulations, or in Kantorian terms that it results from "setting effects" (Kantor, 1958). He rightly pointed out that generalised imitation has been demonstrated and investigated in experiments where multiple sources of control, including the participants' (unknown) reinforcement histories, verbal extra-experimental variables, and other synchronic variables (such as the experimenter's presence or the choice of models), were likely to be operating. Similar arguments and supporting data have been presented by several other investigators, who recognised that—being verbal—most of the participants in generalised imitation studies were responsive to instructions provided by the experimenters, as well as likely to self-instruct. For example, in several experiments, three to nine year old children matched nonreinforced probes unless they were told or shown that it was acceptable not to do so (see Peterson & Whitehurst, 1971; Sherman, Clark, & Kelly, 1977; Steiman, 1970; Waxler & Yarrow, 1970).

"Setting effects" critiques have rightly pointed out that most of the generalised imitation experiments were poorly suited to answering questions about how matching behaviour develops, the adequacy of matches, or indeed any other topic mentioned in the discussions of
imitation so far, because they mainly used participants who were already proficient imitators with extensive social experiences and skills, and who were old enough to name the modelled actions as well as to respond to complex instructions. However, no experimental data have been adequately explained through "setting effects" analyses, because the explanations of verbal behaviour, instructional and self-instructional effects, and the kinds of experiences needed to establish the matching behaviours in the first place, have not been presented.

The Conditioned Reinforcement Account

Baer and colleagues have presented the most plausible functional account of generalised imitation so far (Baer & Deguchi, 1985; also see Baer, Peterson, & Sherman, 1967; Baer & Sherman, 1964). According to these authors, operant matching training is provided in early social interactions; many correspondences between a caregiver's and her infant's behaviour are so trained. The stimulus class of behavioural similarity between the model's actions and the observer's own responses, that is the sole common feature of all reinforced matching responses, becomes discriminative with respect to social reinforcement, and thereby established as a conditioned reinforcer in its own right. Thereafter, the conditioned reinforcement of similarity serves to strengthen any new responses which produce or achieve it. The reinforcing property of similarity is derived from its discriminative function; therefore generalised imitation remains dependent on the availability of at least some external reinforcement in any one context.
Baer and Deguchi (1985) have been careful to point out that this analysis appears simple only at first inspection, because "similarity" is a complex stimulus dimension. They suggested that appreciation of the class of correspondences between own and others' actions may depend on some prior experiences, and that such experiences could be lacking in special, non-imitative populations. Analysis of the procedures that are necessary to establish generalisation of similarity among large sets of stimuli, and determining how these procedures may work, were presented as outstanding empirical questions.

The authors discussed two related predictions of the conditioned reinforcement account. Firstly, the reinforcing properties of similarity ought to be demonstrable in paradigms other than imitation; some of these paradigms should, ideally, allow the independent manipulation of behavioural similarity. Secondly, the reinforcing property of similarity would be expected to be responsive to manipulations of primary reinforcers with respect to which similarity is discriminative.

There is some evidence that children find behavioural similarity reinforcing: they prefer being imitated by adults to being responded to contingently in other ways (Baer & Deguchi, 1995; Gopnik, Meltzoff, & Kuhl, 1999). However, most studies to date have investigated participants' judgments of sameness or similarity between simultaneously or sequentially presented stimuli, and not the more complex judgments of behavioural similarity. A comprehensive review of all the studies that
have investigated discriminations of sameness and difference in children (and in primates) is outside the scope of the present thesis.\textsuperscript{5}

Baer and colleagues did not discuss the possibility that abilities (and not just experiences) needed for "appreciation" of the complex dimension of behavioural similarity may be restricted to certain species. By contrast, Miller and Dollard speculated that human mental processes may be higher precisely because of our "greater capacity to respond selectively to more subtle aspects of the environment as cues" (Miller & Dollard, 1941, pp. 72).

\textbf{Generalised Imitation in Infants: A Very Brief Review}

As noted earlier, the behaviour analytic literature contains virtually no generalised imitation studies with infants and young children. This is in keeping with the general trend: "basic" human research is done, almost exclusively, with adults and older children. This trend is at variance with

\textsuperscript{5} In brief: Many have debated the multiple senses of "sameness" and "similarity" that have been used and tested in the literature (e.g. Benett, 1983; Premack, 1983). The most popular paradigms included: preferential looking at novel relationships in infants (e.g. Tyrell, Stanffer, & Snowman, 1991; Tyrell, Zingaro, & Minast, 1991); matching-to-sample in children and primates (e.g. Bhatt & Wright, 1992; Spinozi, 1996; Thompson & Oden, 1996); novelty-preference in children and primates (e.g. Thompson, Oden, & Tyrell, 1992). Overall, children did better than primates (e.g. Premack, 1988); very young children and older children with developmental disabilities were found to be slow to learn on matching-to-sample tasks (e.g. Dube, Iennaco, & McIlvane, 1993; Serna, Dube, & McIlvane, 1997).
the behaviour analytic theoretical emphases on learning and histories of reinforcement.⁶

For example, Waxler and Yarrow justified their investigation of the conditions that affect the maintenance of generalised imitation in school-age children by stating that, "by implication, these may have a bearing also on its origins" (Waxler & Yarrow, 1970, pp. 128). However, this line of reasoning is faulty, not least because the control of behaviour may be fundamentally altered in verbal organisms (Horne & Lowe, 1996, 1997, 2000; Vygotsky, 1987; and see Baer & Deguchi, 1985).

In the only two infant studies reported to date, Poulson and colleagues examined generalised imitation of object-directed actions in 11-18 month old children (Poulson & Kymissis, 1988), and echoing (generalised vocal imitation) in 9-15 month old children (Poulson, Kymissis, Reeve, Andreatos, & Reeve, 1991). Three parent-infant dyads participated in each study; parents served as models.⁷

Infants aged 11 months at the start of the study and 14 to 18 months at the end, were tested for generalised imitation of object-directed behaviours. Fifteen toys were presented to infants in each session, one at a time; each

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⁶ The same applies to work on human schedule performances, stimulus equivalence, and relational framing. For critiques see Horne and Lowe (1996) and McIlvane (1999).

⁷ Although theories and data on vocal imitation are not reviewed in the present thesis, the second study is included because it represents 50% of behaviour analytic data on generalised imitation in infants.
toy presentation lasted one minute. In baseline sessions, mothers were instructed to play with their infants but not to model target actions on toys; in the treatment sessions, mothers asked their infants to, "Do this" and modelled target actions on the corresponding toys. Each infant was presented with 45 different toy-action pairs; mothers were instructed to praise infants' correct matching responses on 30 of these toys; the remaining toy-action pairs (15) were used as probes and correct matching responses were not reinforced. Poulson and her colleagues reported that infants emitted more target responses on reinforced and probe trials in treatment (modelling) sessions than in the baseline (no-modelling) sessions.

Over 70% of all target actions were produced in baseline trials, prior to modelling; children's target responses in baseline showed steady frequency increases across trials. Mothers reinforced up to half of the children's target responses emitted in baseline sessions (they were not instructed not to). The introduction of modelling, praise for correct matching, and instructions to imitate, did not affect this trend much, for either the praised trials or the silent probes. Yet the authors reported that infants showed generalised imitation of (unreinforced) modelled actions. Their conclusion was based on the differences in means of target actions between baseline and test conditions, which would have been expected to differ through a growing trend alone. These extremely variable data could have been more appropriately described (analysed) by the celeration method (Kazdin, 1982), but this was not done.

Poulson and colleagues used conventional object-directed actions that were
(see above) within their participants' repertoires, and common toys with limited affordances. This left their data open to re-interpretation in terms of all of the non-imitative matching processes discussed in Chapter 2, save for behavioural contagion. For example, many target actions could have been established outside the experiments as trained matches, while emulation, on-line cueing and shaping, and extra-experimental parental training between sessions may have occurred. Given all the processes that could have contributed to childrens' correct matching of target models, the weakness of the modelling effect is surprising; the authors' claim that generalised imitation was demonstrated is certainly unwarranted.

Similar objections regarding lack of appropriate controls can be made for the echoing study. Infants, aged between 9 and 15 months, were exposed to parental modelling of nine sounds each; six of these sounds were used as training-target models; the remaining three were used as probe-target models. The target sounds were extracted from the individual infants' baseline vocalisation measures. During experimental sessions, parents asked, "Can you say [model]" and presented all target sounds; in the first condition praise was not given for any matching sounds; in the second condition parents praised infants' matching vocalisations for training-targets only.

Poulson and colleagues reported that (i) children showed some matching of the target sounds before praise was introduced; (ii) children's matching of all target sounds increased when parental praise was introduced for trained-target models.
For two out of three infants there were growing trends in matching of sounds prior to praise; the effects of praise were not strong. Although only the vocalisations already in the infants' repertoires were chosen for modelling, a range of approximate vocalisations were scored as "matches". Poulson and her colleagues did not recognise that nonverbal cueing by parents could be functional within the experiments (only parents' verbal praise was recorded); this betrayed a naive conceptualisation of social reinforcement. They never discussed the possibility that their target behaviours may have been trained as matches extra-experimentally, although they explicitly excluded such matches from their definition of generalised imitation. This distinction has not been made in other behaviour analytic studies either; its importance for the interpretation of the generalised imitation data is discussed in the following headings.

**From Matching Training to Generalised Imitation: Data from Special Populations**

The only behaviour analytic data showing the acquisition of generalised imitation came from studies with participants from special populations. These findings are certainly valuable, but ought to be interpreted with care because the conditions shown to be effective in "special" populations

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8 Therefore, these data did not show truly generative imitation (as defined in Chapter 1). Further, the authors asserted that the generalised imitation effects demonstrated in this study were specific to the target vocalisations, as no increases in other vocalisations
may have differed from the "normal" developmental variables (see Poulson & Kymissis, 1988).

As mentioned in the earlier summary, operant matching training has been reported to result in generalised imitation of a range of actions and vocal gestures in apparently nonverbal and nonimitative participants (Baer, Peterson, & Sherman, 1967; Lovaas, Berberich, Perloff, & Schaeffer, 1966). The experimenters typically reported using putting through, shaping, and fading procedures, usually with verbal prompts ("Do this") and food reinforcement coupled with praise. Many trials were initially needed to establish behavioural matches; the probability of correct responding on first trials increased as the training progressed. For example, Baer, Peterson, and Sherman (1967) reported that putting through was needed to establish the first gestural (action) matches, but as the number of trained matches in the participants' repertoires increased, shaping alone was sufficient to establish the new ones. The probability of good matching on the first trial steadily increased from 0% at the start, to about 50% after some 50 matches, and to 80-100% after 130 different matches were emitted and received reinforcement. Also, reliable vocal matching was established only after extensive prompting and shaping of the initial responses. Finally, once participants were able to match single actions and vocalisations on the first presentations, increasingly longer chains were modelled and matched.

were found. This was due to ceiling effects: "other" vocalisations occurred in a large majority of baseline trials (80 - 90%), and the scoring was categorical.
At least two of the variables in this study differed from the "normal" developmental data: (i) the use of food reinforcement, and (ii) the participants' ability to reproduce lengthy chains of actions, which is limited in infants and very young children (see Carpenter, Akhtar, & Tomasello, 1998; Fenson & Ramsay, 1981; cf. Donald & Muir, 1998).

How did matching training work to produce (generalised) imitation in these participants? Baer and colleagues suggested that a broad class of similarities have been made discriminative for reinforcement, and became (conditionally) reinforcing. However, direct demonstration of the reinforcing property of similarity was not provided in these studies (and see Peterson, 1967). The authors gave virtually no descriptions of the matches, or the errors commonly made by the participants.

Garcia, Baer, and Firestone (1971) reported that generalisation of behavioural matching developed within topographically determined boundaries, and remained restricted to the action types that were used in matching training (small gestures, large body movements, vocal responses) in previously nonimitative children. This finding may be interpreted as showing how different subclasses of similarity have been established as discriminative and therefore reinforcing in several consecutive stages of matching training.

These findings were replicated with autistic children (Young, Krantz, McClannahan, & Poulson, 1994). However, the participants in this study likely received some echoing training and were presumably showing some matching prior to the experiment. It is possible that the restriction of
generalised imitation to the topographical types used in matching training may have been due to the instructional effects. Thus, rather than serving to teach the participants to discriminate (and produce) the relevant subclasses of similarity, the experimental training may only have served to single out some of the already discriminable similarities as predictive of reinforcement in the novel experimental context (see later discussion).

Overall, it remains possible that similar effects were obtained through different mechanisms in different studies. Some of the participants may have in fact learned to discriminate and achieve behavioural similarity through the experimental manipulations; others may have had some of the relevant experiences and abilities prior to the testing, learning only to respond in compliance with the (implicit) contextual demands; some may have been competent enough to respond verbally.

The last option was presumably unavailable to the non-human participants in the comparative "Do-as-I-do" studies, which resembled the generalised imitation experiments in that many different actions or gestures were trained as matches by putting through and shaping procedures, and contingent reinforcement was provided for matching on command. These studies are briefly reviewed next.

**Comparative Data: Generalised Imitation in Primates?**

In most of the comparative studies, the stated aim of the "Do-as-I-do" paradigm was not to provide training for imitation, but to establish a reliable contextual cue (usually the verbal command "Do this"), which
could later be used to probe the imitative abilities of "enculturated" primates.

In the first study of this kind, Hayes and Hayes (1952) claimed that after matching training of only 12 different actions, their home-raised chimpanzee Vicky started to imitate on the first trials, providing that the modelled actions were in her repertoire (frequently emitted elsewhere, nonimitatively), and that after 20 matches were established she became able to imitate entirely novel actions and gestures. Unfortunately, the details of training and testing procedures were not presented in this early report.9

Custance and colleagues attempted to correct the omissions of the much-cited Hayes and Hayes' study; they reported a replication with two young chimpanzees (Custance & Bard, 1994; Custance, Whiten, & Bard, 1995; and see Whiten, 1999). In the first phase, lasting over three months, extensive matching training with 15 gestures was provided.10 In the

9 Baer and Deguchi (1985) listed Hayes and Hayes' (1952) study as the first demonstration of generalised imitation in the literature, preceding the Baer and Sherman (1964) classic experiment with children. Regrettably, no replication of these data have been reported in behaviour analytic literature. Further, behaviour analysts who study generalised imitation remain unaware of the more recent and better controlled comparative data (e.g. Poulson, 1999).

10 Probes with 6 gestures similar to the trained ones revealed that the chimps were not proficient imitators at the end of this training, because their matches were inexact and
second phase, 48 different gestures from 6 "categories" were modelled several times each, interspersed with trained matches, with reinforcement provided continuously but non-contingently with respect to the accuracy of chimps' matching. The authors reported that chimps either responded with familiar gestures (spontaneous or taught), with modifications of the taught matches, or with apparently novel but inexact approximations to the target models.\(^\text{11}\)

Custance, Whiten, and Bard (1995) provided fairly detailed descriptions of the individual chimps' matching attempts. The experimenters' use of a wide range of visible and invisible gestures excluded many alternative explanations (elicitation, emulation, local enhancement, affordance and individual learning). Thus this study was better controlled than most of those with human participants presented in this and the following chapter.

However, both chimp participants had extensive "enculturation" histories, and it is possible that some of the "novel" target gestures were established as matches outside the experiment. Further, the multiple presentations of similar to the trained gestures. However, no further training was provided due to time constraints (see Custance, Whiten, & Bard, 1995).

\(^{11}\) Custance et al. proposed that the use of conspecific models may improve performances by making it easier to "map" own to others' actions (or note the similarity between the two). They also suggested that the "Do this" command may not have controlled perfect matching, presumably because of the type of training provided (i.e. reinforcement for all responses).
target gestures could have provided opportunities for on-line shaping and cueing by the familiar trainer who served as the model, leading to the observed modifications of the taught actions. This could have been sufficient to inform the coders' guesses (as to the action that was "imitated" in each trial) which were used as data to support the authors' claims that the chimps imitated, albeit imprecisely (see Heyes, 1998, for a similar critique, and cf. Bard, 1998; Custance, 1998; Whiten & Custance, 1996).

An orangutan, Chantek, was trained to match the modelled actions on ASL (gestural) command. It was reported that Chantek was able to match a range of simple gestures and conventional actions on objects in formal and informal testing (see Call & Tomasello, 1990; Miles, 1990). However, in a later study, Chantek was unable to imitate (on command) simple actions that were modelled in the context of an instrumental task, after exposure to a large number of demonstrations of lever pushing, pulling, or rotating for food reinforcement (Call & Tomasello, 1990). The authors suggested that the "imitation game" learned in one context failed to transfer to the novel problem-solving situation.

This finding resembled the topographically-bound generalisation effects found in the human generalised imitation studies. Like the human participants, the orangutan was also a veteran of several training programmes; the gestural matching data ought to be interpreted with caution because of the uncharted history of gestural training and of possible on-line cueing effects. Similar criticisms could be made about "imitation" of actions on objects shown by two enculturated chimps who were instructed to "Do what I do" by a human model, and corrected
(taught) when they failed to match correctly, after training that was briefly described as preparatory (in Tomasello, Savage-Rumbaugh, & Kruger, 1993).

In the most convincing demonstration of generalised imitation in non-human participants to date, Herman (1999) reported that fairly brief training was sufficient to establish a gestural command (transcribed as "mimic") as the cue for behavioural matching in dolphins. After matching training with 10 different actions, these animals were able to match 15 test actions, three of which were novel. Overall, the four dolphins were reported to match (on command) known actions, object manipulations, strings of behaviours previously trained to gestural commands but not as matches, and novel actions, modelled either by humans or other dolphins, live or televised (see Herman, 1999; Herman, Pack, & Morrel-Samuels, 1993; Kuczaj II, Gory, & Xitco, 1998). Further, one of the dolphins was trained to mimic various arbitrary sounds, some of which were quite unlike its natural repertoire, when presented with an auditory cue.

Herman and colleagues also reported that the dolphins were able to: (i) reproduce their own behaviours and match others' behaviours after imposed delays of up to 80 seconds, (ii) match novel and physically impossible human actions with approximations, (iii) choose appropriately when commanded to "person mimic" or "dolphin mimic" and presented with a choice of models, (iv) match selectively on request but not in response to a control command, and (v) imitate in synchrony a dolphin model's novel and uninstructed improvisations.
The possible shortcomings of these studies, performed over a long period of time and involving several different experimenters, are difficult to pinpoint, given that the training and testing arrangements necessarily differed from those used with primates and humans (e.g. dolphins are physically incapable of gesturing, can attend simultaneously to the trainer standing in front of them at the pool side and to another dolphin performing in water behind them). All that can be said is that the experimenters were aware that Akeakamai, Phoenix, and the other two dolphins were sophisticated and sensitive to human company and cueing (they received extensive listener training and were tested in all kinds of cognitive and matching-to-sample tasks; see Herman, Pack & Wood, 1994). Therefore, the experimenters attempted to control for the alternative, nonimitative matching processes; their controls were superior to those that have been employed with human and primate participants (Herman, 1999; also see Chapter 2). Overall, the impressive data of Herman and colleagues await replication from another lab.

**Is Matching Training Necessary and Sufficient for Imitation?**

"We attempt to show how one must learn to learn through exposure to models' responses." (Gewirtz & Stingle, 1968, pp. 383)

The behaviour analytic research published to date has not accomplished the goal stated in the opening quote, namely to show that (generalised) imitation is, or must be, learned.
An unequivocal demonstration of imitation in neonates (see the next chapter) would conclusively show that imitative abilities are innate. By contrast, no amount of research demonstrating that contingency manipulations affect the matching performances of sophisticated, already imitative participants can possibly show that imitation is learned, or shed much light on the mode of its acquisition.

The learning argument is best put forward on the grounds of parsimony. It is unnecessary to evoke "special", innate abilities to account for human imitation if it can be shown that (i) early social interactions contain contingencies for training of behavioural matches, and that (ii) all matching in very young infants can be accounted for in terms of such direct matching training.

The behavioural analytic literature contains no functional analyses of early social matching training. Few such reports have been provided in the developmental literature (see Chapter 4). For example, Moran and colleagues recorded and analysed short periods of spontaneous play of 20 mother-infant dyads; the infants were between 13 and 16 months old (Moran, Krupka, Tutton, & Symmons, 1987). The authors reported that mothers engaged in highly contingent matching of their babies' actions; the babies were reported to engage—much less frequently—in "simultaneous imitation". These data are consistent with matching training: contingent maternal matching could have acted as a reinforcer for infant behaviours; if these behaviours were immediately repeated, this would establish mothers' actions as discriminative stimuli for infants' matching responses (also see Kaye, 1982; Uzgiris, 1993). Overall, more
detailed analyses are necessary to show that matching training is a universal feature of dyadic play in infancy and childhood.

Contrary to the authors' claims, the infant data presented by behaviour analysts (Poulson & Kymissis, 1988; Poulson, Kymissis, Reeve, Andreatos, & Reeve, 1991), and by developmental researchers (see next chapter), do not demonstrate conclusively that infants and young children show imitation of novel behaviours\(^\text{12}\). The matching abilities of children under two years old, in these studies, were consistent with generalisation of matching relations directly trained by caregivers (as well as aided by non-imitative matching processes, reviewed in the previous chapter). However, no infant study to date has set out to show directly that children will show matching of behaviours that have been directly trained as matches, but not of behaviours that are equally easy to perform and that had no such training history.

Studies in which apparently non-imitative participants from special populations are shown to acquire large matching repertoires through direct matching training (Baer, Peterson, & Sherman, 1967; Lovaas,

\(^{12}\) A minimal definition of imitation, presented in Chapter 1, states that

Imitation can be said to occur when (i) an observer emits behaviour that is similar to that of a model, after seeing the model's behaviour, (ii) the behaviour in question is novel for the observer, (iii) the observer's behaviour is directly caused by seeing the model's behaviour—and not by something else—and (iv) no external reinforcement is necessary.
Berberich, Perloff, & Schaeffer, 1966) can provide corroborative evidence for the learning hypothesis.

Non-human research, reviewed in the previous heading, also has the potential for providing complementary evidence in organisms whose natural environments do not provide the required matching training, and whose training histories can, in principle, be more tightly controlled (Miller & Dollard, 1941).

**What Generalises in Generalised Imitation: Determinants of Children's Matching Behaviour**

As discussed in Chapter 2, many non-imitative learning processes can result in an observer's apparent matching of modelled behaviours. This is especially true of object-directed actions, of behaviours that are already in the observers' repertoires, and of object manipulations that are performed on objects with limited affordances. Most of the behaviour analytic experiments employed modelling of conventional, non-arbitrary, object-directed actions. This was also true of most of the cognitive developmental data reviewed in the next chapter. Therefore, most of "imitation" reports with human children do not show conclusively that modelling determined the observers' responses directly, let alone demonstrate that the apparent matching was imitative.

If all of the above alternative learning processes are controlled for, say in experiments where the target behaviours are multiple arbitrary actions on objects that do not have limited affordances, or gestures performed
without objects, modelling of target actions can still evoke matching in several different ways. Apparent emergent matching of target models in an experiment could be the result of: (i) generalisation of trained matching, (ii) verbal control of behaviour, and (iii) generative imitation. These three possible determinants of children's matching performances are discussed in turn.

**Generalisation of Trained Matching**

Early social interactions are said to include operant matching training of a range of behaviours (e.g. in conventional games and nursery rhymes). Thus ever-increasing repertoires of trained matches are established in infancy and childhood.

Trained matching is likely established as several response classes with different topographies (e.g. gestural matches, object-directed actions, vocalisations). The appreciation of the complex relational property of physical similarity between discriminative stimuli and responses is not necessary for the formation of such classes. For example, a response class of "gestural matches" could be "held together" by virtue of the physical relationship (of similarity) between the discriminative stimuli (all are gestures performed by others), or between the responses (all are own gestures), or both (see Catania, 1994).

In these early stages of matching training, "similarity" is not special, except for the caregivers (see Skinner, 1953, 1957). In principle, very large repertoires of trained matches may be acquired in this way.
Indeed, extensive training histories of matching may be necessary before children become able to respond to the complex stimulus dimension of similarity between others' models and their own responses (Baer & Deguchi, 1985).

These early response classes would be expected to contain at least some non-matching responses as well; for example, in English-speaking countries, the commonly trained response to a "palm up" gestural model is not a matching gesture but a complementary one (as in "gimme five"). If generalisation of trained matching—and not imitation—is responsible for the apparently emergent matching of target models in an experiment, then reinforcement of some of the matching responses ought to support the performances of both the remaining trained matching responses and the trained non-matching, complementary responses.

Experimenters could explicitly include modelling of behaviours that would have likely been trained with non-matching responses, as a control. They ought to examine whether children's incorrect responses contain such complementary responses, and whether these persist over time (are maintained by the reinforcement given for some of the matching responses). Another way of determining whether similarity between one's own and others' behaviours acts as reinforcement is to train sets of novel matching and non-matching responses to gestural models, and see whether it is easier to train the matching responses, or whether the similarity makes no difference (see Skinner, 1953).

Peterson (1968) reported the results of such a test with a developmentally
delayed, non-speaking, 12 year old child. This participant was exposed to operant matching training of several different behaviours (mostly gestures); her matching generalised to several behaviours in the absence of reinforcement. Next, the participant was trained several non-matching behaviours, such as twisting a toy knob when presented with a hands-behind-neck gesture and stretching a rubber band when presented with a hand-to-mouth gesture. After the training was complete, these responses were subjected to extinction.\textsuperscript{13}

In a subsequent test, modelling of gestures that were established as discriminative stimuli for non-matching responses was interspersed with modelling of gestures that were directly trained as matches. Reinforcement was provided only for the correct matching responses; however, the participant consistently emitted the trained non-matching responses as well. Peterson concluded that, "imitative behaviours may also be members of an even larger class which includes non-imitative behaviours" (Peterson, 1968, pp. 233).\textsuperscript{14}

\textsuperscript{13} Unfortunately, it was not reported whether operant training of non-matching responses took longer than that of matching responses.

\textsuperscript{14} The author cautioned against overgeneralisation of the results, obtained with a single, older, and developmentally delayed child.
To summarise. Generalisation of trained matching can result in matching of novel combinations of previously trained behaviours, and in "approximate" matching of novel modelled behaviours that are physically similar to the trained ones (and see the next heading). In most experiments with children such approximations are coded as "correct". When participants' histories of trained matching are not known, it ought to be assumed that all apparently emergent matching of conventional behaviours in an experiment is due to generalisation of trained matching, and not to imitation (as defined in Chapter 1, and see below). Many of the "generalised imitation" experiments ought to be re-interpreted as showing generalisation of trained matching.

**Verbally Controlled Matching**

Many have argued that (vocal) imitation may be a necessary prerequisite for language learning; few have discussed the reverse relationship, namely that language learning may affect children's matching of actions and gestures (e.g. Miller & Dollard, 1941; and see the "setting effects" heading above). According to Horne and Lowe (1996), the control of behaviour is often fundamentally altered in verbal organisms (see below); this is likely to be true of matching behaviour.

It is difficult to establish whether children emit verbal responses (such as naming of actions, or more complex self-instructions in older children) in matching tests, because these responses need not be overt. For example (and using the Horne and Lowe terminology), a child presented with modelling of a hand-to-ear gesture could respond as a speaker and say,
"ear". This child could then respond as a listener to his or her own utterance and touch the ear, thus matching the model correctly.\textsuperscript{15}

Overall, the experimenters have to take into account that (covert) verbal behaviour may be functional in matching performances of children who have learned to name. This has seldom been discussed by the authors of generalised imitation studies with pre-school and school-age children (e.g. Baer & Sherman, 1964). However, such studies ought to be parsimoniously re-interpreted as showing generalisation of trained matching and verbally controlled matching, not imitation.

The notion that verbal behaviour learning may alter children's matching performances is testable. For example, training a child to name a body part that is then touched in modelling may result in correct matching of a previously unmatched hand-to-body gesture. However, no such experiments have been presented to date.

\textit{Imitation: Higher-Order Matching}

Entirely novel behaviours can be matched when children become able to respond to the common feature of all the trained matches, namely the

\textsuperscript{15} Verbal control may be especially important in "pretend play" paradigms: it has been reported that children start matching such behaviours correctly only towards the end of their second year (see Chapter 4 and Killen & Uzgiris, 1981; McCabe & Uzgiris, 1983; Uzgiris, 1984).
similarities between the modelled behaviours of others and their own responses. The stimulus class of similarity, discriminative with respect to reinforcement, becomes reinforcing in its own right (Baer & Deguchi, 1985). Thereafter, those of the child's varied responses that achieve similarity with the modelled behaviour are reinforced and likely to be repeated. Such shaping could likely occur overtly and take some time in young children, and become covert and quick in "proficient" imitators (see Miller & Dollard, 1941).

The term "generalised imitation" has been used in behaviour analysis to label all apparently emergent matching that occurs in an experiment in the absence of external reinforcement. As discussed above, apparently emergent matching in an experiment could be the result of several different processes: generalisation of trained matching, or verbally controlled matching, or truly generative matching, or any combination of these. These matching processes are all interesting in their own right; however, using a common label for clearly different sources of control creates confusion. For example, the three different theoretical accounts of generalised imitation (presented above) can be seen as complementary, explaining different processes that can result in "generalised imitation". Thus Gewirtz' account mostly refers to generalisation of trained matching; Steinman's account emphasizes the verbal control of matching, while Baer and colleagues' account explains how truly generative matching could be acquired and maintained.

Therefore, it is proposed that the term *higher-order matching* can be used to label generative matching that is established and maintained through
(secondary) reinforcement of similarity between one's own and others' behaviours (and see Palmer, 1996, for a discussion of "parity").

It is higher-order matching that most behaviour analytic authors refer to when they discuss the role of generalised imitation in child development. The minimal definition of imitation, presented in Chapter 1, specifies that a range of novel behaviours ought to be matched. This is not so in generalisation of trained matching (where only directly trained responses, and perhaps combinations of these, can be matched). The further requirement for imitation is that the model's behaviour controls the observer's matching behaviour directly. This is not so in verbally controlled matching. Therefore, higher-order matching is the only "generalised imitation" process that meets the criteria for unmediated, generative imitation.

No behaviour analytic study to date has demonstrated higher-order matching in infants or in young children. As discussed earlier, several studies with special populations have shown that matching training can lead to generalised matching of many other behaviours. However, in these studies, generalisation of trained matching could not be ruled out: participants were reported to emit previously trained responses to novel models that resembled the trained ones, and the experimenters used shaping to correct these responses (e.g. Baer, Peterson, & Sherman, 1967). The same applies to the comparative, "Do-as-I-do" studies with primates.
Behaviour Analysis of (Generalised) Imitation: Future Directions

Behaviour analytic research, with its emphasis on experimental control of individual participants' performances, is uniquely well placed to examine the determinants, constraints, and scope of infant matching, the role it may play in learning of conventional behaviours (see Horne and Lowe, 1996, 1997, 2000; Kyrnissis & Poulson, 1990; Poulson & Kyrnissis, 1988), and the changes in matching behaviours which may result from naming and other verbal behaviour developments.

The wealth of ideas and data from comparative psychology, reviewed in the previous chapter, have been unexplored by behaviour analysts so far. The variables highlighted in the contemporary comparative literature—their classification of non-imitative learning processes, and the suggested experimental controls needed for unambiguous demonstration of imitative abilities—ought to be used to inform future research.

A thorough critical examination of the extensive literature on imitation in developmental psychology could, at the very least, provide a starting point for designing a coherent behaviour analytic research programme; it would also enable behaviour analysts to communicate with their colleagues from different theoretical backgrounds (see Morris, Hursh, Winston, Gelfland, Hartman, Reese, & Baer, 1982). This was recognised by Poulson and colleagues, who published a good, now dated, review of imitation in infancy research (Poulson, Nunes, & Warren, 1989). A critical review of cognitive developmental data and theory is presented in the next chapter.
CHAPTER 4

Active Intermodal Mapping: A Review of the (Cognitive) Developmental Literature on Imitation

Early Imitation of Facial Gestures

"What can we infer from the fact that very young infants can match simple facial acts? It is not likely that any single experiment will define the underlying psychological mechanism, this will only be decided by weighing a large set of converging experiments." (Meltzoff & Moore, 1994, pp. 84)

It has been reported that newborn babies show selective matching of facial (and manual) gestures that are modelled by adults; infants in their first 6 months of life are also said to show imitation of gestures; older infants (between 9 and 14 months old) are said to show immediate and deferred imitation of object-directed actions (see Meltzoff and Moore, 1999).

If the claims for neonatal imitation of facial gestures can be substantiated, this would indicate that imitation need not be learned, is independent from external reinforcement, involves innate cognitive abilities for cross-modal matching of visual and proprioceptive stimulation, and (possibly) direct links from perception to action, or generative perception. The neonatal data suggest a major causal role for imitation in early development as
opposed to it being only derived from the latter. Therefore, these reports
deserve a thorough critical examination.

Findings with neonates, in their first few days of life, and those with young
infants, usually in their second month or older, have routinely been
discussed together, under the label of "early imitation" (e.g. Heimann,
1999; Meltzoff & Moore, 1992, 1997). However, different interpretations
can be suggested for the neonatal and later infancy findings, which also
varied with respect to the methods of testing. They will therefore be
discussed separately.

A Note on the Imitation of Invisible Acts

Many theorists, past and present, have suggested that the imitation of
"invisible" (opaque) actions ought to be investigated separately from
matching of visible (limb) or audible (vocal) gestures (see Chapter 1; also
see Anisfeld, 1991; Heyes, 1999; Meltzoff & Moore, 1997; Miller & Dollard,
1941). There are at least two reasons for this.

It is impossible for human beings to see, and thereby compare directly,
their own facial responses to the facial movements of others (unless they
use a mirror to do so). Therefore, the matching of such "invisible" gestures
has been said to necessitate cross-modal comparison of the seen act with the
stimulation produced when the observer attempts to perform that act.
This has been contrasted with comparing one's own "visible" actions and
the actions of others that can be accomplished using only the visual
modality, allowing, of course, for the differences in perspective between one's own acts and those of others.

There are many ways in which apparently cross-modal matching can be trained. First, a cross-modal matching repertoire could be trained directly, relation by relation, through differential reinforcement and shaping. Second, children could be trained to vary their responses until their reflection in a mirror matches the acts that they see modelled. Third, children could be trained to discern a correspondence between what they see and what they feel when they are told (or via a mirror they see) that their responses are good matches. However, training a cross-modal matching repertoire in any of the ways outlined above would be a lengthy process. Therefore, a convincing demonstration of imitation of invisible acts (such as facial gestures) in newborn babies is incompatible with the learning accounts of imitation.

Neonatal Imitation Data

Most studies that have investigated neonatal imitation of facial gestures employed a cross-target paradigm in which a single adult modelled two or more alternative facial expressions. Two kinds of expressions have been used: full-face emotional expressions, and discrete oral gestures.
Neonatal Matching of Emotional Expressions

Field and her colleagues (Field, Woodson, Cohen, Greenberg, Garcia, & Collins, 1983; Field, Woodson, Greenberg, & Cohen, 1982; also see Meltzoff & Moore, 1977) reported that term and preterm babies discriminated between three emotional expressions. Discrimination was measured in a habituation/novelty paradigm, as length of fixation to repeated modelling of the expressions versus presentation of new expressions. Further, the authors reported that neonates imitated some components of the exaggerated emotional expressions of sadness (frowning and pursed lips), happiness (grinning), and surprise (wide open mouth and eyes). The authors attempted to guard against inadvertent shaping of the infants' responses by recording and examining the experimenter's actions, but the possibility of subtle contingent changes in experimenters' posture and handling of infants remained.

The procedures used by Field and her colleagues have been criticised in several ways. Modelling of each expression was presented for as long as infants looked; individual infants were presented with up to four times more modelling trials for some expressions than for others; individual trials varied in duration within and between infants. Field and colleagues did not report whether infants as a group found some expressions more interesting than others (e.g. whether there were consistent differences in looking times between the three expressions). If such was the case, and if infants' interest was accompanied by a high occurrence of one of the coded mouth movements (e.g. open mouth), the reported effect(s) could have been due to this, and not to imitation (also see later discussion).
The forced choice scoring of "imitation" and "expressiveness" by observers could have promoted guessing based on the participants' head and eye-movements, and possibly back-of-head model's movements, which differed between the modelled expressions (see Anisfeld, 1991). For example, Field and colleagues (1982) reported that infants predominantly looked at the model's mouth when presented with happy and sad expressions, but alternated gaze between mouth and eyes when presented with the surprised expressions. Consequently, the coders guessed that infants "imitated" surprise much more consistently (76% of trials) than was the case for sadness (59%) or happiness (58%).

When the coders were allowed to refrain from guessing in a later replication study, no matching of the three expressions or their components was found (Kaitz, Meschulach-Sarfati, Auerbach, & Eidelman, 1988).¹

**Neonatal Matching of Oral Gestures**

The second and more commonly cited group of neonatal studies examined matching of discrete, mostly oral, gestures. It has been reported that

¹ The use of the coders' subjective judgements as the sole dependent variable in any imitation study is questionable. However, Whiten (1999) suggested that, because matching could occur at various levels of similarity, it may be good to supplement the comparably objective data of response (or component) frequencies with a more qualitative and holistic assessment of this kind.
neonates imitated (i) tongue protrusion (TP), (ii) mouth opening (MO), (iii) head rotation, (iv) lip pursing, (v) lip widening (smiling), and (vi) hand opening and closing (Heimann, Nelson, & Schaller, 1989; Kaitz, Meschulach-Sarfati, Auerbach, & Eidelman, 1988; Meltzoff & Moore, 1983, 1989; Reissland, 1988; Vinter, 1986). In marked contrast to the findings with young infants in their first few months of life (see the next heading), the participants in these studies were reported to imitate all of the gestures that were presented to them.

The coding criteria for neonates' responses varied between experiments; many approximations were usually admitted as correct matches. For example, Reissland (1988) coded tongue protrusion, lip protrusion, and small mouth openings with the tongue visible, as imitation of lip pursing.

Most of the listed gestures were employed in only one of the studies; therefore, the findings for these gestures have not been replicated. Increases in the frequency of neonates' tongue protrusion in the periods where this gesture was modelled and neonates' responses tested remains the only replicated result. Further, Ullstadius (1998) failed to replicate even this finding within a more "natural" setting, where mothers acted as models for tongue protrusion and mouth opening.

All of the gestures that were used in the neonatal studies were emitted at high frequencies in baseline (in the absence of modelling). Reports of "imitation" were not therefore based on first time appearances of such gestures after exposure to adult modelling, but on the comparative frequencies of each gesture in trials when it was modelled as opposed to
trials in which an alternative gesture was presented. In almost all studies tongue protrusion was one of the two gestures that were modelled. As Anisfeld (1996) pointed out, the selective changes (increases) in babies' frequencies of tongue protrusions could have influenced the frequency distribution of both alternatives, producing "false positives" for the second gesture.

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As discussed in Chapter 1, neonatal data can be explained by behavioural contagion. At most, only a small number of acts are evoked by presentation of the corresponding models and the effects are transient (see the next heading; also see Russon, Mitchell, Lefebvre, & Abravanel, 1998). Bjorklund (1987) suggested that early matching behaviours should be classified as "transient ontogenic adaptations" that serve to maintain social interactions, and are therefore discontinuous with later imitation (also see Kaye, 1982; Miller & Dollard, 1941).

If only tongue protrusion findings are reliable (see below), even this interpretation may be too rich, because all that needs to be explained is the high frequency of a single action that can be elicited by the corresponding gesture of the model (Abravanel & Sigafoos, 1984), as well as by non-social stimuli such as pen movement (Jacobson, 1979).

Jones (1996) presented data for four week old infants showing that (i) the frequencies of tongue protrusion increased in the presence of displays that babies found interesting, (ii) tongue protrusion modelling attracted more
attention (longer looking times) than modelling of mouth opening. She also reported that infants' tongue protrusion frequencies declined with the development of reaching and mouthing (oral exploration). Jones concluded that tongue protrusion may be an early form of (attempt at) oral exploration.

Yet another interpretation was offered by Abravanel (1991); he suggested that neonates' attention to interesting displays may temporarily lead to inhibition of tongue protrusion, which is a common and frequent baseline behaviour, only to result in a burst of this gesture after the presentation, due to disinhibition. This could account for the apparent "matching" in the most common paradigm, where repetitive cycles of short modelling and response periods are used.

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Reports of neonatal imitation (Meltzoff and Moore, 1977, 1983) were hailed as ground-breaking discoveries; later publications that argued that these results are an artifact of faulty coding procedures, and cannot be replicated, gained much less prominence (e.g. Anisfeld, 1979, 1991, 1996). In the latest such experiment, Anisfeld and his colleagues reported only small increases in the frequencies of tongue protrusion following a corresponding model and no matching of mouth opening (the second most used gesture in neonatal studies) in newborn babies exposed to modelling of these facial gestures. This study used the largest sample reported so far (83 babies), and refined coding and reliability analyses. The authors concluded that
These results reinforce the conclusion that emerges from a critical analysis of previous research; namely, that there is little basis for the hypothesis that neonates can imitate oral gestures. The widespread acceptance of this hypothesis may be due in part to its dramatic appeal and to the predilection to attribute innate competencies to babies." (Anisfeld, Turkewitz, Rose, Rosenberg, Sheiber, Couturier-Fagan, Ger, & Sommer, 2001, pp. 121)

Early Imitation Data

Studies conducted with somewhat older infants, who were usually between two and six months of age, once again commonly relied on modelling of a small set of oral gestures, but employed somewhat stricter timing of modelling and response periods, and finer coding of infants' responses, as compared to neonatal studies. However, procedural critiques indicating several likely sources of experimenter bias, misguided coding, and faulty analyses, have been put forward by Anisfeld (1991) and B.R. Moore (1992). For example, according to these critics, Meltzoff (in some of his early studies) placed his finger as a pacifier into each infant participant's mouth, while he modelled the target action; this odd practice enabled him to anticipate and direct the infant's tongue protrusion and mouth opening responses, and may have biased the results.

Selective imitation—in this age group—of oral, head, and manual gestures, has been reported in several studies (Legerstee, 1991; Meltzoff & Moore, 1992, 1994, 1997; also see Heimann, 1999). Many other studies of similarly aged infants found little or no matching across gestures, models, and age groups tested (Abravanel & DeYong, 1991; Abravanel & Sigafoos,
1984; Fontaine, 1984; Heimann, Nelson, & Schaller, 1989; Lewis & Sullivan, 1985). However, several authors who found little evidence of matching went well beyond the data in interpreting their results. For example, Heimann, Nelson, & Schaller (1989) tested a group of infants shortly after birth, at three weeks old, and at three months old. Out of three target models, lip protrusion was rare throughout and was excluded from the analyses, mouth opening was fairly frequent but not matched at any age, and small approximations to tongue protrusion were found to increase in frequency after modelling at the two earliest ages only. Yet the authors concluded that their data provided a demonstration of imitative capacity in young infants, and went on to discuss individual differences in this capacity within their sample (also see Heimann, 1989; Meltzoff & Moore, 1999).

In a critical review of the literature, Anisfeld (1991) concluded that only tongue protrusion increases were reliably obtained. Further, the cross-sectional data indicated that the limited matching seen at the earliest ages (four to six weeks) disappeared later on, usually by the age of two to three months (see Abravanel & DeYong, 1991; Abravanel & Sigafuos, 1984; Fontaine, 1984; Heimann, Nelson, & Schaller, 1989; also see Field, Goldstein, Vega-Lahr, & Porter, 1986).

The elicitation and oral exploration re-interpretations of tongue protrusion in the neonatal data (see previous heading) can be extended to this set of findings for older infants. However, these possibilities have been repeatedly rejected by Meltzoff and Moore (e.g. 1977, 1997, 1999; also see Heimann, 1999). These authors questioned the validity of the experiments
that have reported replication failures on the grounds that the researchers employed inadequate recording equipment and small sample sizes, and also that they pre-exposed the infants to the experimenter (model), which may have dampened infants' responses in subsequent imitation tests (Meltzoff & Moore, 1983).

These objections do not appear to be valid, because: (i) if early imitation is restricted to particular kinds of artificial settings, its role in development is questionable (also see Lewis & Sullivan, 1985); (ii) early imitation is said to be ubiquitous; yet large sample sizes of over 40 infants are said to be needed to detect the minute effects of modelling; (iii) babies are said to learn through imitation in social contact with their caregivers, whose faces are familiar, yet familiar faces are said to be ineffective as models.

Regarding the latter point, Meltzoff & Moore (1992, 1994, 1997, 1999) argued that early facial imitation may be used by babies as an identity probe in situation where ambiguities exist. For example, in one study, it was arranged that the experimenter and infants' mothers present modelling of two different facial gestures (one each) in succession; some infants emitted a burst of the previously modelled gesture when confronted with the next model (mother vs. experimenter). Meltzoff and Moore suggested that infants used re-enactment of a previously modelled gesture to "probe" whether the person they encountered on each trial was the same person who had presented the modelling on the previous trial. They went on to assert that, for infants, "imitation is to understanding people as physical manipulation is to understanding things" (Meltzoff & Moore, 1994). However, it is implausible that two month old infants
needed to imitate facial gestures in order to "recognize" their own mothers (e.g. see Slater and Kirby, 1998, for a review of data showing that infants of this age show excellent face discriminations, and strong preference for their mothers' faces).

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The possibility that some facial gestures can be trained as (operant) matches in very young infants has seldom been acknowledged (see Chapters 2 and 4), although face-to-face dyadic interactions, occurring daily in the first months of babies' lives, could easily support such learning (e.g. see discussion of "proto-conversations" in Trevarthen, Kokkinaki, and Fiamenghi, 1999; however, these authors explicitly rejected the learning hypothesis). Thus some (most?) of the target gestures that were used in the imitation studies could have been directly trained as matches by caregivers.

For example, in two related experiments, target gestures included tongue protrusion to the front and to one side of the mouth, and mouth opening. The experimenters argued that the gesture of tongue protrusion to side was novel for most infants; mothers were asked to describe the kinds of "games" that they played with their infants (six weeks to three months old). Several mothers reported that their infants routinely produced the target gestures, including the one that was supposed to be novel, in the context of
such games; the experimenters excluded these infants (Meltzoff & Moore; 1992, 1994).²

In these experiments, each infant participant was exposed to modelling of oral gestures but was prevented from immediate responding by placing a dummy in its mouth. The infants' responses were recorded after modelling ended, when the dummy was removed. The findings of delayed matching of the target gestures within the experimental context—assuming that some of these were already established outside the experimental context as trained matches for at least some of the participants—can be reinterpreted as follows. If, in the experimental context, it is not the case that one adult models all of the target gestures, but that for each of the latter only one adult serves as the model, then the particular adult, rather than the gesture that he or she models, may become discriminative for the target response when the opportunity is provided to perform it. The effect on deferred performance of the target behaviour would probably be weak and transient, but possibly sufficient for obtaining significance with very large samples. If so, deferred matching effects could depend on the use of different adult models for different gestures. This was indeed the procedural prescription strongly recommended by Meltzoff & Moore (1992, 1994).

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² Parental reports cannot be considered as a sufficient control; it is possible that target gestures were trained as matches for the remaining babies also.
Yet another confounding mechanism could have worked to produce false positives in some of the early imitation studies. Many of the participants were probably old and experienced enough to be affected by the facial, gaze, and postural cues of the models, who were always supposed to present a neutral expression during the response periods. Thus on-line cueing and shaping of successive approximations to correct responses remained a possibility (see Chapters 2 and 4 for discussion of this non-imitative matching process). The models' performances were occasionally recorded but usually not analysed, because the possibility of cueing and on-line shaping of the babies' responses has seldom been explicitly considered as a viable alternative explanation for matching. For example, Legerstee (1991) reported that care was taken not to record the model's gesturing, in order to make the coding truly blind (it did, with respect to any occurrence of on-line cueing).

As described earlier, Meltzoff and Moore (1994) presented six week old infants with the alternative models of tongue protrusion to the side and to the front of the mouth (as well as with a neutral face baseline condition and a mouth opening gesture). The authors reported that different responses were produced between the groups of babies exposed to one of the two tongue protrusion variants, with the performances "converging" on the target (measured for the side protrusion only) over three days of modelling and testing. However, the possibility that these actions were in some of the participants' trained matching repertoires, and of on-line shaping and cueing, make these results equivocal.

To summarise.
Non-imitative processes, such as elicitation, trained matching, on-line shaping, and "perceptual tethering" (whereby infants' simultaneous tracking of the seen movement can lead to matching, e.g. of lateral head movements; see Meltzoff & Moore, 1989), can account for the published neonatal and older infants' matching data. Only demonstrations with neonates, who are presented with a variety of gestures other than tongue protrusion, in a within-participant design (see McCall, Parke, & Kavanaugh, 1977; Poulson, Nunes & Warren, 1989), can provide conclusive evidence for innate imitation. All studies ought to analyse the models' actions, scheduled and unscheduled, throughout the experimental procedures.

The matching data presented so far do not provide convincing evidence that imitative performances and cross-modal matching are present either at birth, or in the first six months of life. The observed relative increases of the frequencies of target behaviours during or after the modelling could have been due to a number of different phenomena, such as those outlined above (see Chapter 2), as well as to procedural errors.

Finally, the reports of individual differences in early matching (see Abravanel & DeYong, 1991; Field, Goldstein, Vega-Lahr, & Porter, 1986; Heimann, 1989, 1999; Heimann, Nelson, & Schaller, 1989; Meltzoff & Moore, 1983, 1992, 1994; and see Poulson, Nunes, & Warren, 1989), while intriguing, cannot be interpreted without a clearer understanding of the functional relationships which may have differed between the individual babies and the paradigms employed to investigate their behaviour.
Imitation as Active Intermodal Mapping

"We can say with assurance that the capacity to imitate certain facial acts is truly an innate aspect of the human mind." (Meltzoff, 1993, pp. 229)

The opening quote presents the view held by the great majority of contemporary developmental authors. As noted earlier, procedural critiques of neonatal and early imitation experiments are in the minority (and cited only as an example of stubbornness of its authors; see e.g. Butterworth, 1999); published replication failures are likewise seldom mentioned in the literature. The most influential theoretical account of imitation, presented by Meltzoff and Moore (see Meltzoff & Moore, 1985, 1990, 1992, 1994, 1995, 1997, 1999; also see Meltzoff, 1990, 1993), is based on reports of imitation in neonates and young infants.

In an early paper, Meltzoff and Moore wrote that

"In our view, this early imitation reflects a process of active intermodal mapping in which infants use the equivalences between visually and proprioceptively perceived body transformations as a basis of organising their responses." (Meltzoff and Moore, 1985, pp. 124; italics in the original article)

The authors elaborated on the exact mechanisms of infants' active intermodal mapping in their later publications:

"First, organ identification is the means by which infants relate parts of their own bodies to corresponding ones in adult's. Second, body babbling (infants' movement practice gained through self-generated activity) provides experience
mapping movements to the resulting body configurations. Third, organ relations provide the metric by which infant and adult acts are perceived in commensurate terms. In imitating, infants attempt to match the organ relations they see exhibited by the adults with those they feel themselves make." (Meltzoff & Moore, 1997, pp. 179; italics in the original article)

Meltzoff and Moore asserted that imitation in infants (i) is present at birth but also changes during development, (ii) can be demonstrated over a range of acts, including novel ones, and (iii) involves quick activation of appropriate effectors and self-correction. Therefore, Meltzoff and Moore have argued that infant imitation is representationally mediated, goal directed ("matching-to-target"), and generative. This account of imitation will henceforth be referred to as the active intermodal mapping theory of imitation.

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The active intermodal mapping theory of imitation is presently accepted as an explanation of infant imitation, and has seldom been directly challenged. Other developmental authors have presented complementary theories about the social context and scope of infant imitation (e.g. Trevarthen, Kokkinaki, & Fianmenghi, 1999; Uzgiris, 1999), about changes in imitation during infancy (e.g. Butterworth, 1999; Kugiumutzakis, 1999), and about the varied roles it plays in communication and other forms of learning (e.g. Nadel, Guerini, Peze, & Rivet, 1999).
Chapter 4  
Active Intermodal Mapping

The majority of (cognitive) developmental experimenters have tested matching of object-directed actions in infants from nine months to two years old. A critical review of these data, which have also been interpreted as consistent with the active intermodal mapping account of imitation, is presented next.

Infant Matching of Conventional Actions on Objects

Once again, the most influential reports of the imitation of object-directed actions in infants between 9 and 24 months old came from the writings of Meltzoff and his colleagues (see Barnat, Klein, & Meltzoff, 1996; Gallagher & Meltzoff, 1996; Hanna & Meltzoff, 1993; Heinmann & Meltzoff, 1996; Meltzoff, 1985, 1988a, 1988b, 1988c, 1990, 1995a, 1995b, Meltzoff & Gopnik, 1989; Rast & Meltzoff, 1995). Meltzoff and colleagues have reported that infants (i) imitate a range of different actions, including novel ones, (ii) imitate adult, peer, and televised models, and (iii) show imitation even if the opportunities to respond to modelling are deferred for many weeks or even months.

A set of "standardised" objects, target actions, testing arrangements, and experimental controls, have been reported in these papers. The following critique addresses the procedural issues for this influential experimental programme as a whole; references to individual papers are presented when appropriate.
A Critique of Meltzoff and Colleagues' Imitation Paradigm

Target Objects' Familiarity

Meltzoff and colleagues have claimed that the target objects employed in their experiments were novel (unfamiliar) for infants, because these objects were constructed in the laboratory and were not commercially available, or, if bought, they were modified in some way. However, all the target objects closely resembled conventional toys, parts of toys, and other household items, with which the participating infants were likely to have been familiar. The following object-action pairs were used in most experiments: (i) a dumbbell toy that was pulled apart; (ii) an L-shaped object consisting of two wooden pieces—a base and a flap—joined by a hinge; the flap was pushed down (as if closing a book); (iii) a small box with a recessed button that was pushed (and so produced a beep); (iv) a plastic egg that was rattled (to produce noise); and (v) a small, stuffed bear toy with a string attached to its top; the string was held and bear jiggled to make it "dance" on the tabletop. Meltzoff (1988c) also used a large plastic box with a translucent top that lit up when touched (with a head touch).

As discussed in Chapter 2, the use of familiar-looking (conventional) objects is expected to result in high baseline occurrences of the corresponding conventional behaviours. The conventional behaviours listed above were designated as target actions in all the experiments; consequently, infants' baseline performances of target actions were often high. For example, Meltzoff (1988c) reported that imitation of some of the target actions did not reach statistical significance because of "ceiling
effects": most of the participants pushed a button and closed a hinged L-shape without being exposed to modelling of these target actions (and see below).

The use of conventional, non-arbitrary object-action pairs can bias the results in the opposite direction as well. If comparably less frequent actions are chosen as targets, the modelling of these target actions and the infants' previous histories of object manipulations may set up competing sources of control. For example, Meltzoff (1988b) reported that infants did not imitate the "bear-dancing" target action; most of the participants engaged in the more conventional play with the teddy instead (e.g. hugging, poking). In another example, Hannah and Meltzoff (1993) found that a target action of pulling a block by a string (on the tabletop) was poorly matched; even the peer-expert models, who were directly trained to produce this target action, often preferred to do something else (dangle the suspended block).

Target Objects' Affordances

Most of the target objects employed by Meltzoff and colleagues had very limited affordances. The target objects could only be manipulated in certain ways; further, they generated interesting consequences (e.g. changes in shape, or of the sound they produced) only when handled "appropriately". As discussed in Chapter 2, objects with limited affordances can promote on-line learning of the corresponding target actions.

For example, several studies used a wooden, L-shaped object (described
above). The corresponding target action of closing the flap was virtually the only action that this object afforded: the object was too heavy to be lifted or moved by infants; further, Meltzoff (1988b) reported fastening the target objects to the table with velcro strips.  

The use of objects with limited affordances can promote correct matching of modelled actions in several ways. For example, infants may match the modelled approach to an object (e.g. gripping with the whole hand vs. poking with one finger); the rest of their manipulations may be shaped by the consequences provided by the objects themselves (and see Meltzoff, 1985). In this scenario, matching (probably previously trained outside the experimental setting, see below) of the initial approach to an object may serve to give a small but sufficient advantage to the infants presented with modelling of target actions over those that have not been exposed to modelling; the infants exposed to modelling of "alternative" actions would have been put at a disadvantage (see Charman and Huang, 1999; also see below). All infants exposed to objects with limiting affordances may end up producing the correct target actions through individual exploration and learning (see Chapter 2 for discussion); however, those exposed to modelling may do so faster. "Imitation effects" may therefore be an artifact of short response intervals.

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3 As discussed in Chapter 2, the experimenter used "alternative" actions, supposedly as a control for social stimulus enhancement due to adult's handling of objects (see below for a critique). However, the L-shaped target object afforded no alternative action; therefore the experimenter dissembled the object to model the alternative (sliding) action; he then presented infants with the unmodified object in the testing.
Heinmann and Meltzoff (1996) used longer response intervals (30 seconds instead of the usual 20) with a Swedish sample, because these infants appeared to be more cautious than their American peers. More target actions were recorded for all infants (in imitation and control groups); the authors did not comment on this finding. It seems appropriate to ask: if the response intervals were to be made even longer, would "imitation" effects still be observed? Has the 20 second interval been established as a norm because it has been observed that most infants studied lost interest and stopped playing with the objects within 20 seconds, or because statistically significant effects were not obtained with longer intervals?

**Novelty of Target Actions**

In contrast to the early imitation data, Meltzoff and colleagues reported that older infants imitated the target actions on objects perfectly, straight away. If any of the target actions were novel, this would indicate that older infants' matching abilities are more advanced than those of younger infants. However, the more likely explanation is that infants matched the target actions correctly because these were well practiced, known responses. As noted above, infants' target responses were scored categorically (whether or not they appeared in 20 second long response intervals). If the infants did not self-correct to achieve target responses, then it was unnecessary to record their behaviour over pre-determined time intervals; the experimenter ought to have coded only their first responses after modelling (see Charman and Huang, 1999).

Meltzoff (1988c) discussed the various ways in which an act can be said to
be novel; he settled for the criterion of near-zero occurrence in baseline (without exposure to modelling; see Chapter 1). According to his own criteria, the target actions used in most of the presently discussed studies were not novel in any sense. For example, Meltzoff (1985) singled out the 7.5% baseline occurrence of one of the target actions (a string-pull) as small. Certainly, most reported baseline scores were higher than this, often substantially. However, any spontaneous occurrence of a target action, within short baseline periods, indicates that the acts are familiar.

Meltzoff (1995a) reported that 18 month old infants reproduced actions that were modelled as "failed attempts"; thus infants produced most of the target actions although they did not see them modelled in their entirety. Meltzoff argued that these data show that infants understand other's intentions and imitate the corresponding intended actions; he failed to comment on the fact that this finding demonstrated that none of the five target actions presented in this study—and that have been used in most other studies—were in any sense novel for these infants.

The strongest claims have been made for infants' imitation of a head-touch action, modelled on a panel that lit up as a result (Meltzoff, 1988c). This was the only target action, across the presently reviewed studies, that was not emitted in baseline (by a group of children who had not been exposed to modelling; see below). However, Charman and Huang (1999) argued that head-touches are known and frequent actions for most infants. These authors reported that Meltzoff's data could not be replicated: in their study, infants did not match this action reliably; "imitation effects" were not found when only the first responses to modelling were analysed.
Baseline Control Group

The most basic imitation experiments in the developmental literature have employed two groups of participants: an imitation group that was exposed to modelling of target actions, and a control group that was not. Differences in the production of target behaviours between these two groups are reported as imitation effects (further controls have also been employed in many studies; see below).

Meltzoff (1995a) claimed that measuring the spontaneous production of target acts in a control group not exposed to modelling of these acts provides a sufficient control for the effects of individual on-line learning through objects' affordances. As discussed earlier, this is not so. In any case, the authors did not employ baseline control groups in order to determine the appropriateness of the target objects; these groups were included as a minimal control for apparent matching. Thus Meltzoff (1988c) reported that, with groups of 12 infants, imitation effects for some object-action pairs did not reach statistical significance; this was because very high rates of target actions were obtained in the group that was not exposed to modelling. Instead of concluding that these object-action pairs should not be used in future studies, the author remarked that larger groups would be needed for statistical significance. Subsequent studies from the same lab employed the same object-action pairs but used much larger group sizes; they reported significant imitation effects.

A baseline group control cannot inform the experimenters whether a target action is frequently emitted by individual infants. In the only
experiment where individual infants acted as their own controls, Rast and Meltzoff (1995) assessed the occurrence of target actions in free-play; the same infants were then exposed to modelling. Individual participants were given "imitation scores": percentages of matched target actions were calculated only for those acts that infants did not emit prior to modelling. The results were then discussed for the group; the authors reported that infants imitated six target actions, although many individual participants' scores were calculated for three, two, or even a single action.

**Alternative Action (Adult Manipulation) Control Group**

An alternative action (adult manipulation) control group was employed in several experiments as a control for social stimulus enhancement (see Chapter 2). In brief, it is possible that infants who are exposed to any adult manipulation of objects may later find these objects more interesting, especially if adults' handling of the objects produced interesting consequences (such as light, sound, or changes of shape). When given the opportunity to respond, these infants may engage with the objects more readily, and therefore produce more target actions, than the infants in a baseline control group, who did not observe adult object manipulations (see Devouche, 1988).

The alternative actions that were modelled to control groups of infants were described as simple but unusual, non-obvious behaviours that could
be produced on target objects. Meltzoff and colleagues reported that, in several experiments, infants in the adult manipulation groups did not emit more target actions than infants in baseline control groups.

According to Meltzoff and colleagues, these findings showed that the comparably higher occurrence of target actions in the groups exposed to modelling of these actions was due to imitation, and not to social stimulus enhancement of particular features of the target objects.

Charman and Huang (2002) argued that adult manipulation controls often presented the infants with touches which, in relation to the target actions presented in the main modelling condition, were directed at irrelevant parts of the objects; therefore stimulus enhancement was not controlled for in this condition, as would have been the case if target-action-relevant parts were touched. It could be said that an adult manipulation control presented "negative" stimulus enhancement. Indeed, in some of the studies, infants in the alternative action groups emitted fewer target responses than did those not exposed to any modelling (e.g. Meltzoff, 1988b). This would not have happened if, as claimed by Meltzoff and colleagues, the alternative manipulation provided stimulus enhancement comparable to that present in the modelling of the target actions.

As discussed earlier, some such actions could not be performed on the target objects; the objects needed to be modified in order to afford them.

By contrast, target-relevant features of objects were touched in Meltzoff's (1995a) experiment that reported infant imitation of intended but uncompleted acts; these data
A similar argument can be made with reference to emulation processes. As discussed in Chapter 2, the matching of object-directed actions can be interpreted as the result of emulation, whereby children exposed to modelling learn about how an object moves, and then effect the same movement (especially if modelling resulted in reinforcing object transformations, such as making an object light up).

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As noted earlier, Meltzoff and colleagues computed imitation effects by calculating the difference between the number of target responses emitted by infants exposed to modelling of target actions and those emitted by infants in the two control groups. The authors usually added up, and considered together, the scores from the baseline control group and those from the adult manipulation control group. The rates of target responses could have been lowered in these two control groups in different ways: (i) the baseline group was not exposed to adult manipulation of target objects, or to the objects themself, prior to their handling; therefore, infants could have been more cautious and less interested in the target objects than those in the modelling group; this could have lowered their rates of all object manipulations, including target behaviours; (ii) emulation and "negative" social stimulus enhancement could have lowered the rates of target behaviours in the adult manipulation group. Overall, the two could therefore be explained by social stimulus enhancement (or emulation). Also see Carpenter, Akhtar, and Tomasello (1998).
groups did not provide, individually or jointly, appropriate control for apparent matching of target actions.

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As discussed in Chapter 2, one control for non-imitative matching processes, suggested in the comparative literature, is the multiple-action procedure (e.g. Whiten, 1999). In this procedure, two or more alternative actions are modelled on the same objects, and selective matching of all alternative actions is taken as evidence for imitation. Providing that (i) the target objects do not contain limited affordances, (ii) the alternative actions do not result in different object transformations that can lead to matching through emulation, and (iii) all target actions are novel and equally difficult to perform, matching of all alternative actions can be taken as evidence of imitation.

By contrast, Meltzoff and colleagues did not measure infants' performances of alternative actions in baseline, or after modelling, in all but one of their studies. In the last experiment from the series, Barnat, Klein, and Meltzoff (1996) reported that (i) infants emitted many target actions in baseline; the alternative actions were not emitted, and (ii) infants' matching rates for alternative actions were much lower than those for target actions. The authors did not dwell on this confirmation of the familiarity of the target acts (and the likely effects of objects' affordances); instead, they stated that infants' limited matching of the alternative actions, "strengthens the inferences that can be drawn by showing that imitation in 14-month olds extends to a range of novel acts" (Barnat, Klein, & Meltzoff, 1996, pp.
Trained (Operant) Matching and On-Line Cueing of Target Responses

As Discussed in Chapters 3 and 4, many of the conventional behaviours that Meltzoff and colleagues have used as target actions could have been established extra-experimentally, by caregivers, as trained (operant) matches; trained matching would be expected to generalise to the experimental context. The authors have never commented on this possibility.

It is also possible that parents (and the experimenter, and other adults who were present in testing in some of the experiments) could have cued the infants' responses in test trials. Because all the responses within

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6 In the first paper that reported inclusion of an adult manipulation control group, Meltzoff (1985) remarked—in a footnote—that some infants seemed to mimic some aspects of one alternative action (a circular movement performed on a dumbbell toy; the corresponding target action was pulling apart); they produced small twisting motions. Meltzoff did not remark that this alternative action may have been quite novel, while the target one was not; but stated that, "the manner in which motor constraints and other factors interact to influence whether infants try to imitate at all, and when they do, what features of the display they choose to duplicate, is an interesting topic that must be left for future studies" (Meltzoff, 1985, pp. 68). And left it was: the prolific publications from the same lab, spanning over 10 years, did not report measurements of matching of alternative actions.
predetermined intervals were coded, on-line cueing could have shaped infants' actions in immediate imitation tests (see Chapters 2 and 4).

Even more likely, parents could have provided (un)intentional training of target responses at home, prior to the deferred imitation tests. In the most cited report of infant imitation of a novel act (head touch of a panel, see Meltzoff, 1988c) modelling was presented to the infants and parents (infants were seated on their parent's lap); imitation was tested after one week. Parents, who likely wanted their children to "do well", had a full week in which to train this "novel" target response (and the other five target responses) at home. The same critique applies for the other reports of deferred imitation in infants (see Chapters 2 and 3).

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To summarise. The infant matching of object-directed actions data presented by Meltzoff and his colleagues cannot be accepted as evidence of imitation. The data are open to re-interpretation in terms of any one, or a combination of, the non-imitative matching processes discussed in Chapter 2, save for behavioural contagion. This is true also of many other studies published to date in the (cognitive) developmental literature. A critical review of the developmental imitation data from other labs is presented next.
Infant Matching: Developmental Changes

Kaye and Marcus (1978, 1981) investigated the matching of conventional behaviours by infants aged between 6 and 12 months. These studies are interesting because the authors did not code infants' behaviours categorically as "correct" (or "approximations"), as was the case in most other studies.

Kaye and Marcus (1978) discussed the varied responses that six month old infants were found to make in response to many trials of adult modelling of a repetitive mouth opening gesture. Unlike the later reports of early imitation of facial gestures (see previous headings), the authors noted that infants responded to mouth opening and closing not only with mouth gestures, but also with (open/close) hand movements, arm movements, vocalisations, and pulling of clothes. These responses would not be predicted by the active intermodal mapping theory of imitation. However, the authors' report that infants' matching improved over repeated trials cannot be accepted, because only a single action was modelled; it is possible that infants would have produced increasing rates of mouth movements in response to repeated modelling of other-than-mouth gestures.

Kaye and Marcus (1981) reported longitudinal data from infants who were exposed to modelling of several conventional behaviours (e.g. clapping, shaking a toy, vocalising) from 6 to 12 months of age. Overall, infants' matching got better over time; for some of the responses (e.g. touching an ear with the index finger), entirely correct responses were not recorded. The individual differences were great and children did not get better.
smoothly. The authors reported that, because of the variability and individual differences, analysing the data for infants as a group became meaningless; they also emphasized the importance of repeated (multiple) trials and of detailed coding of the infants' responses. As discussed above, the later developmental publications did not follow these suggestions.

The authors reported that the experimenter, who modelled the target behaviours, was well trained and carefully monitored so as not to respond contingently to the infants' performances; this level of (appropriate) caution has seldom been reported in developmental papers. However, they did not discuss the possibility that the mothers, who were present in all sessions, could train the target behaviours extra-experimentally. Therefore, the children's matching of the conventional (mostly gestural) target responses in these experiments is open to re-interpretation in terms of generalisation of trained matching.

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Uzgiris and her colleagues explored imitative mother-infant interactions and matching of actions on objects, gestures, and vocalisations, in infants from 2 to 22 months old.

In a series of studies, Uzgiris and colleagues (see Killen & Uzgiris, 1981; McCabe & Uzgiris, 1983; Uzgiris 1984), tested infants' matching of (i) conventional object-action pairings, such as putting a toy phone to the ear and drinking from a cup, (ii) contra-conventional object-action pairings, such as putting a cup to the ear and drinking from a toy phone, (iii)
conventional behaviours modelled on abstract shapes, and (iv) conventional behaviours modelled without objects, as gestures. Infant participants were aged between 7 and 22 months old; infants' mothers and the experimenter served as models.

Infants performed many of the target (conventional) actions in free play with the corresponding target objects. It was found that (i) at the youngest ages (7 months) infants showed little or no matching of target actions; (ii) overall, matching performances increased and improved over the ages tested; (iii) conventional actions modelled on abstract objects were matched by older but not by younger children; (iv) contra-conventional object-action pairings were consistently matched only by the oldest children; (v) conventional actions that were modelled as gestures were matched much less frequently than those that were performed on the corresponding objects. Further, children matched about equally well when the mothers and the (unfamiliar) female experimenter modelled the target actions.

The procedures of Uzgiris and colleagues can be criticised as follows: (i) too many children's responses were coded as approximations to correct matches (e.g. banging a car on the table, once, was coded as an approximation of a car-driving target action); (ii) the experimenters instructed mothers not to praise or otherwise cue their infants' responses; however, the behaviours of the mothers and of one or two experimenters that were present in the testing were not recorded or analysed. Therefore, these data are open to re-interpretation in terms of trained matching, on-line shaping, and emulation (as discussed above).
Similar data were presented by Masur (1993) and Masur and Ritz (1984). These studies reported infants' matching of maternal actions, gestures, and vocalisations; the testing was conducted in infants' homes by pairs of experimenters (the procedural critique applies to these data also). Infants were aged between 10 and 21 months old; maternal reports were used to determine the relative novelty of the target actions, all of which were conventional.

It was found that (i) overall, matching rates and accuracy increased with age; (ii) infants matched the more familiar modelled behaviours better than the less familiar ones; (iii) infants matched familiar gestures better than less familiar actions on objects. Those infants who were firstborn showed better matching than those who were not. Masur (1993) argued that infants' experimental matching may be related to their experience of imitative social interactions with their mothers; the firstborns' greater matching behaviour was interpreted as due to their comparably greater exposure to such interactions.

The Social Context: Early Matching Games

Uzgiris (1984) presented the findings of a study designed to explore the nature and frequency of imitative interactions in dyadic play. Infants were between 2 and 11 months old; mothers were given some conventional toys and asked to play with their infants. These interactions were analysed for mothers' matching of infants' behaviours and vice versa. It was found that, at the earlier ages of 2 and 5 months, most of the imitative play
consisted of mothers' matching; at the later ages, the infants' matching increased and mothers' matching remained frequent.

Uzgiris reported that, on average, 9.5 sequences of matching were recorded for each dyadic interaction that lasted up to 12 minutes; there were marked differences between individual dyads. Mothers often modelled conventional actions on objects; they did so more directly, frequently, and persistently with older infants. In turn, older infants matched such actions. Overall, most of the matching sequences were recorded for manual actions and gestures; fewer were recorded for vocalisations (also see Kuczynski, Zahn-Waxler, & Radke-Yarrow, 1987; Rodgon & Kurdek, 1977).7

These data were consistent with previous analyses of early social interactions in the developmental literature (see Uzgiris, 1984, for a review). For example, Pawlby (1977) reported that dyadic interactions were found to contain many matching sequences; in the majority of these episodes mothers matched their infants' behaviours, and not vice versa. Such studies used cautious coding (of marked changes in behaviour, and of behaviours that follow one another without intervening acts); as noted by

7 Uzgiris interviewed the mothers at the end of recording. Those mothers who modelled and matched their infants' behaviours more often, spontaneously reported that imitation was an important part of their games, and that they made conscious efforts to elicit their infants' imitation. The remaining mothers, who modelled and matched less, did not offer spontaneous comments about imitation; when asked, they reported that infant imitation "just happens".
Uzgiris, it is possible that subtle imitative interactions were even more frequent.

These reports are consistent with behaviour analytic accounts of generalised imitation, which is said to originate in early social interactions (see Chapter 3). Uzgiris wrote that

"There is evidence that behavioural matching does take place in [early social] interactions, but it is uncertain whether it fits the definition of imitation. The infant acts that are matched by the mother are not novel for the mother, but observation of the infant performing them is most likely a determinant of their occurrence. On the other hand, acts that are matched by the young infant may not even involve a direct attempt on the infant's part to match the mother. Nevertheless, once the behavioural match is achieved, it is available to be experienced by both partners." (Uzgiris, 1984, pp. 18)

**Deferred Matching of Conventional Actions**

Abravanel and colleagues (see e.g. Abravanel, 1991; Abravanel & Ferguson, 1998; Abravanel & Gingold, 1985) reported that infants aged from 12 to 30 months showed matching of conventional actions on objects after short delays (10 minutes). In these experiments, infants were presented with modelling of (i) simple actions (e.g. opening a barrel to reveal a smaller one inside), (ii) reiterative actions (e.g. unscrewing a screwnut), (iii) sequential actions (e.g. putting a stick into a tube to push out a doll, or stacking blocks in a particular way).
The authors reported that (i) overall, older infants matched the target actions better than the younger ones; (ii) the younger infants (12 - 13 months) performed better in immediate than in delayed tests, but the older infants (20 months) did equally well in both tests; (iii) the younger infants matched simple but not complex target actions; and (iv) the older infants showed some matching of reiterative and sequential actions.

Abravanel and colleagues' data suggest that action complexity may not be the main determinant of infant matching. While some three-step sequences were matched by most infants, including the younger groups, the remaining three-step sequences were seldom matched. The well-matched sequences contained well practiced responses and objects with limited affordances (e.g. opening of two different kinds of barriers released a ball, which could then be rolled down an incline); the less-matched sequences did not (e.g. a wedge and a plane were arranged to form an incline, on which a set of wheels could roll down).

Abravanel and Ferguson (1998, Experiment 2) demonstrated that 28 month old children's matching of sequences of brick stacking got better if the children were presented with the completed brick configurations as well as with bricks that needed to be arranged; the younger children (22 months) did not profit from this additional model of the objects' "final state" (see discussion of emulation as final state recreation in Chapter 2).

These studies can be criticised as follows: (i) the target actions commonly appeared in free play, in the absence of modelling; (ii) matching effects were calculated by comparing between groups exposed to modelling of
target actions and control groups of children who were either exposed to no modelling or were exposed to alternative adult manipulation of the objects; (iii) parents were present in the experiments; parents' and experimenters' behaviours were not monitored; and (iv) response periods were long (60 to 120 seconds); the scoring of target actions was qualitative and no exact criteria were given (the "best" responses were assigned scores from 0 to 6 to indicate the coders' subjective judgments of the goodness of children's approximations to target actions). As discussed earlier, these procedures left the data open for reinterpretation in terms of virtually any of the non-imitative matching processes described previously.

**Infant Matching of Action Sequences**

Barr and her colleagues (see Barr, Dowden, & Hayne, 1996; Hayne, MacDonald, & Barr, 1997) explored developmental changes in infants' matching of conventional three-action sequences. They tested groups of infants aged between 6 and 24 months. Their procedure was similar to that of Abravanel and colleagues and of Meltzoff and colleagues; the same criticisms apply.

Barr and colleagues presented infants with fluffy animal hand-puppets; the modelled target action sequence consisted of (i) removing a puppet's glove, (ii) shaking the glove to produce a ringing (bell) sound, and (iii) replacing the glove. Infants' responses were recorded, in immediate and deferred tests (after 24 hours), over 90 second intervals; the coding of responses was categorical with respect to the three target actions.
The authors reported that (i) 6 month old infants matched the first target action in the sequence in immediate tests but not in deferred tests; their performances were better after longer exposures to modelled actions; (ii) 12 month old infants matched the first target action in deferred tests; (iii) 18 and 24 month old infants matched two or three target actions in deferred tests.

The effects of modelling of target actions (as compared to a control group not exposed to modelling) generalised as follows: (i) 12 month old infants produced the first target action when presented with a new puppet that differed in colour from the one used in modelling, but only if short delays (10 minutes) were used; (ii) 18 month old infants produced some target actions when presented with a new puppet that was different in colour, and slightly different in shape; and (iii) 21 month old infants produced some target actions when presented with a puppet that differed markedly in both colour and shape.

Barr and Hayne (1996) explored infants' matching of three-action sequences further, in 18 - 19 month old infants. They presented the infants with modelling of (i) "enabling" action sequences (causal sequences in which actions need to be performed in a particular order to attain the end result; e.g. putting a plank on a box, then putting a frog toy on the plank, then pushing the plank in order to make the frog jump), and of arbitrary action sequences (in which actions could be performed in any order; e.g. putting a block on a plank, then putting a frog toy on the plank, then pushing the frog). Infants' responses were tested after seven days; the procedure was similar to that of Barr and colleagues' other experiments.
The authors reported that infants' matching of non-arbitrary action sequences was better than their matching of arbitrary action sequences. This study was a replication of the findings of Bauer and her colleagues, presented next.

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Bauer and colleagues have published extensively on topics of infant categorisation and memory. Their memory experiments (see eg. Bauer, 1992; 1993; Bauer & Dow, 1994; Bauer & Hertsgaard, 1993; Bauer, Hertsgaard, & Dow, 1994; Bauer, Hertsgaard, & Dropnik, 1994; Bauer, Hertsgaard, & Wewerka, 1995; Bauer and Travis, 1993) employed the elicited imitation procedure; in this paradigm the experimenters often provided verbal narratives of their actions during modelling; infants were verbally instructed to match the seen actions. For example, after modelling of teddy-washing was shown, the experimenter would request of an infant, "Here's a dirty teddy, now you give teddy a bath." The rest of the procedures were much the same as in other developmental studies reviewed earlier. Therefore, all the criticisms apply; further, the narrative/instructional effects introduced another likely functional variable in these studies. A brief summary of the findings, which are much cited in developmental literature, is nonetheless included for completeness.

Bauer and her colleagues published several studies that explored immediate and deferred matching of action sequences in 9 to 23 month old infants (see Bauer & Mandler, 1989; 1992; Bauer & Shore, 1987; Bauer &
Thal, 1990; Carver & Bauer, 1999; Mandler & McDonough, 1995). They modelled three types of action sequences: (i) familiar (e.g. undressing a teddy, then putting it into a bath, then washing it with a sponge), (ii) novel-causal (e.g. putting a ball into a cup, then covering it with another cup, then rattling), and (iii) novel-arbitrary (e.g. banging a ring on a block, then spinning the ring, then putting the ring on a dowel). All of the target actions in the sequences were well-practiced responses for their infant participants. The familiar action sequences were routines commonly observed in age-appropriate play; the novel-causal action sequences were constrained (actions had to be performed in the modelled order to attain the end state); the novel-arbitrary sequences were not constrained.\(^8\) The authors recorded and analysed (i) correct matching of the component target actions, and (ii) correct ordering of actions. The response intervals, where reported, appeared to be infant-controlled (i.e. infants were allowed to handle the target objects for as long as they wanted; all their actions were coded).

The authors reported that (i) overall, infants as young as 9 months showed some correctly-ordered matching of the familiar and novel-causal sequences, especially after repeated exposures to modelling of these

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\(^8\) Novel-(causal-)constrained action sequences appeared to be conventional and familiar in many experiments; the authors conceded that the novelty of these arrangements has not been independently demonstrated. Over all experiments, novel-causal sequences should be considered as "quite familiar"-causal action sequences.
sequences;\(9\) (ii) familiar and novel-causal sequences were matched better than novel-arbitrary ones, especially in deferred tests and for the younger infants. Further, 21 month old infants showed poor matching of action sequences in which familiar actions were presented in a reversed order; presumably, because infants' experiences and modelling presented conflicting sources of control.

As discussed above, it is impossible to say exactly which combination of variables were functional for infants' matching in these studies. Nonetheless, Bauer and colleagues have demonstrated that, within familiar play routines, matching of quite complex action sequences can be accomplished by infants in their first two years of life.

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To summarise.

There is no compelling evidence that neonates match invisible acts, or that infants in their first months of life can imitate any behaviours. Therefore, there is no need to postulate innate cross-modal representations as mediators of early imitation. Infants in their first two years of life have been shown to match a variety of conventional actions on objects that afford these actions. It has also been shown that infants, under certain

\[9\] Carver and Bauer (1999), who reported the data for the youngest infants, used pictures of component actions and end-states of action sequences to "remind" infants prior to deferred tests.
conditions, show matching of complex sequences of conventional actions. However, all the reports of imitation of object-directed actions in infants under two years old are open to reinterpretations in terms of non-imitative matching processes. To date, no experiment has utilised the necessary and sufficient controls for all the alternative matching processes. Therefore, there is no compelling evidence that infants under two years old can imitate (as defined in Chapter 1, and see the next chapter), or that their matching involves cross-modal comparisons of their own and others' acts.
CHAPTER 5

The Experimental Chapters: Introduction

The experiments, presented in the following five chapters, were designed to explore the matching abilities of infants and children in their first three years of life.

The term "matching" has been used in the present thesis to describe the instances in which an observer’s behaviour resembles that of a model. It has been argued, in Chapters 2 to 4, that most instances of matching are not imitative (see Chapter 1 and below for the adopted definition of imitation). Matching processes differ between paradigms:

1. Modelling of non-arbitrary actions on objects which have limiting affordances. The processes that can lead to matching of these behaviours are many (see Chapter 2); they include (i) social, stimulus, and local enhancement; (ii) apparent matching through individual learning of objects' affordances; (iii) emulation (goal enhancement, affordance learning, object movement reenactment, and final state recreation); (iv) generalisation of trained matching; (v) verbally controlled matching; (vi) higher-order matching.

2. Modelling of arbitrary actions on objects which do not have limiting
affordances and modelling of gestures. The processes that can lead to matching of these behaviours are fewer and include (i) generalisation of trained matching, (ii) verbally controlled matching, and (iii) higher-order matching.¹

As discussed in the preceding chapters, virtually all the experiments with infants older than six months and with young children were concerned with matching of conventional, non-arbitrary actions on objects with limited affordances. These data did not show that the models' behaviour determined the children's responses directly, much less that the children's matching was imitative.

The experiments presented in the following chapters examined children's matching of arbitrary actions modelled on objects which did not have limiting affordances (Experiment 1) and their matching of gestures that were not object-directed (Experiments 2, 3, 4, & 5). The experiments employed single-participant designs; the advantages of these over the more commonly employed group methodology are discussed below, and in the following chapters.

¹ Behavioural contagion and observational conditioning are omitted from these lists; so is response facilitation. See Chapter 2 for discussion of these processes. For on-line cueing and shaping of children's responses, see below.
Children's Matching of Arbitrary Actions and Gestures:

Predictions

The general predictions are as follows:

- Infants' matching of arbitrary actions and of gestures is expected to be inferior to that reported for conventional, non-arbitrary, object-directed actions. This is because many non-imitative matching mechanisms cannot support selective matching of gestures and arbitrary actions.

- Most of the developmental studies did not employ (scheduled) reinforcement for infants' matching responses; yet most of the children responded to modelling of target behaviours with correct or approximate matching. The behaviour analytic studies reported generalised imitation in infants, children, and special populations. Therefore, in the present experiments, infants are expected to (i) respond to modelling of target behaviours, and (ii) show correct and approximate matching of target gestures and arbitrary actions, in the absence of external (explicit) reinforcement for doing so.

- Virtually all theories of development consider imitation to be a major learning tool within the first two years of life; however, no study to date has provided a conclusive demonstration of imitation in infants. As discussed in Chapter 4, there is no convincing evidence for imitation in neonates and it seems to be the case that imitation is learned in early social interactions, through direct (operant) matching training (see Chapter 3). Therefore, it is expected that (i) older participants (children
over two years of age) will show larger matching repertoires than younger ones (infants under two years old), and that (ii) older infants and children may show evidence of imitation. However, without knowledge of each child's existing matching repertoire, it cannot be predicted whether or not infants will imitate the target behaviours in any one experiment.

Imitation and Higher-Order Matching: Some Theoretical and Practical Issues

In Chapter 1, a minimal definition of imitation, broadly compatible with the uses of this term in the comparative, behaviour analytic, and (cognitive) developmental literature, was presented. Thus:

Imitation can be said to occur when (i) an observer emits behaviour that is similar to that of a model, after seeing the model's behaviour, (ii) the behaviour in question is novel for the observer, (iii) the observer's behaviour is directly caused by seeing the model's behaviour—and not by some other concurrent event—and (iv) no external reinforcement is necessary for the matching behaviour to occur.

A clarification of terminology is in order at this point. The term "imitation", as used in the present thesis, is descriptive; it denotes an ability to match a range of novel behaviours in the absence of direct training for doing so. The definition of imitation specifies what counts as imitation, but it is not intended to explain it. In principle, imitation could be an innate capacity of the human species (as argued by Meltzoff &
Moore, e.g. 1992, 1999), or it could be learned in the course of early social interactions (as argued by behaviour analysts, e.g. Horne & Lowe, 1996). The term "higher-order" matching, as used in the present thesis, refers to one possible explanation of imitation (e.g. see Baer & Deguchi, 1985). In this account, imitation is said to be established and maintained through the (secondary) reinforcing properties of the similarity between one's own and others' behaviours. As discussed in Chapter 3, higher-order matching is the most plausible account of imitation in the literature so far.

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As discussed in Chapter 1, there are many ways in which a behaviour can be said to be novel. For example, a child may not have seen it, or may not have done it, or may not have been trained to match it. The first of these criteria is the strongest; the last, the weakest.

Imitation is said to be generative; children are said to learn to perform behaviours that were not, prior to modelling, in their behavioural repertoires. As discussed earlier, it is difficult—indeed practically impossible—to establish whether any one target behaviour is in a child's behavioural repertoire. However, in a strong demonstration, only the matching of entirely novel behaviours should be taken as evidence of imitation.

Higher-order matching can be demonstrated with behaviours that are novel in a weaker sense. For example, children's matching of a range of behaviours that have not been directly trained as matches would provide
evidence for higher-order matching. In generalisation of trained matching, only behaviours that have been directly trained as matches somewhere, by someone, and perhaps some combinations of these behaviours, can be matched in an experiment. By contrast, matching of behaviours that have not been directly trained as matches, would provide evidence of higher-order matching. This is the case even if such behaviours were emitted previously under alternative discriminative control (and are not entirely novel). This is because, in the absence of direct matching training, only the appreciation of similarity between one's own and others' behaviours can lead to correct matching; the "stronger" novelty of target behaviours is not crucial for this test.

This distinction between behaviours that are not part of a child's behavioural repertoire (and are entirely novel) and those that are not part of a child's trained matching repertoire (and are not necessarily entirely novel) is practically very important. As discussed earlier, it is virtually impossible to establish which behaviours are entirely novel; by contrast, it may be relatively easy to establish which behaviours have not been trained as matches for individual children. One such procedure was employed in the last two experiments in the present thesis; it is described and discussed in Chapters 9 and 10.

On-line Cueing and Shaping

As discussed in Chapter 4, in virtually all of the published infant studies parents were present in the test room; their behaviour was not monitored or reported. Further, these studies seldom recorded or reported what
the experimenter did or said, save for modelling target behaviours; additional adults (assistants) were also present in some of these experiments. Parents' participation was necessary because the experimenter was always a strange (unfamiliar) adult; the warm-up play seldom lasted for more than a couple of minutes before modelling of actions was presented. Thus parents were invited to hold, reassure, and (presumably) encourage the participating children to attend to the experimenter's behaviour and engage with the target objects.

It is possible that the parents, or the experimenter, or both, cued the children's performance of the target behaviours. For example, parents—who likely wished for their children to "do well"—may have presented conditional smiling for "correct" performances, or urged their children to persist in handling the target objects whenever "incorrect" behaviours were seen. Such "on-line cueing" may have shaped the children's behaviour and artificially inflated the rates of correct responses, which would then have been misinterpreted as imitation. Further, in most studies that tested deferred imitation, parents could have directly trained the infants to perform the target responses at home: in these studies, modelling of target actions was presented in one session, and testing of the children's matching of these actions was administered at a later date.

In all the studies in the present thesis, the experimenter familiarised with the participants over a period of several weeks before presenting the experimental tasks; she became a familiar adult to whom children responded freely, as they would have to any other caregivers in the
Nursery. In this way, the need for parental involvement was eliminated; although parents were told about the aims and the methods of the studies, they were unaware of the target behaviours that were employed in any one experiment.

In the experimental sessions, the experimenter never responded differentially to children's "correct" or "incorrect" performances, except when reinforcement for correct matching of some of the modelled behaviours was scheduled (in Experiments 2 - 5). In order to achieve this, she had to exert quite a bit of self-control, especially in the early trials: "normal" adult-child interactions are loaded with directive cues, such as encouragement for "good" responding, corrections for "bad" responding, and verbal comments and instructions. The experimenter presented unconditional smiling for all the children's responses. This served to maintain children's responding to all modelling and one-to-one play with the experimenter. The experimenter did not present the "still-face"

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2 The author served as the experimenter in all five experiments. In addition to this, a group of undergraduate Psychology students from University of Wales Bangor, as a part of their final year projects, collected some of the training data in Experiment 2 (Condition 1 and 2), and 66% of data in Experiment 3 (they tested 12 out of 20 children in this experiment). The students followed the same procedures of familiarisation with the participants; they were trained by the author to model the target gestures correctly. Students' interactions with children were monitored on-line, by the author, in all sessions. Most of the students were female; for consistency and convenience, the experimenter is referred to as "she" in all chapters.

3 An example of the consent forms that were given to parents is presented in Appendix.
expression because this would likely have suppressed children's responding: "still-face" is commonly presented by caregivers as discouragement (when children do something they should not) and not as a part of normal, playful interactions (see Bell, 1999; Poulson & Kymissis, 1988).

In all the experiments in the present thesis, experimenter-child interactions were recorded in split screen; thus the experimenter's behaviour could be examined for unintentional cueing and shaping of the children's responses. This was done as a part of initial coding. No data had to be discarded because of procedural errors: across all children and sessions, the experimenter did not present reinforcement when it was not scheduled, did not name target actions or their component movements, and did not correct children's incorrect responses.4

Other than the lack of directive cues, the experimental interactions were always structured as age-appropriate, conventional play, with an emphasis on turn-taking and give-and-take games with toys and stickers. All participants seem to have enjoyed these one-to-one interactions:

4 It helped that the experimenter did not have a vested interest in children performing either well (as was the case in many developmental studies) or poorly. The stated aim of the experiments was to explore children's matching abilities; no theoretical account that would constrain how early infants ought to be able to imitate, or how well they ought to match, had been adopted. Therefore, the experimenter was genuinely happy when infants responded to her modelling of target behaviours, regardless of how they responded.
whenever the experimenter appeared in the common room, the participating children usually approached her and "asked" (older children verbally, the younger ones by extending their hands to be picked up, or by taking the experimenter's hand and walking to the door which led out, towards the experimental room) to be taken to play.

Apart from eliminating the need for parental involvement, the present procedure allowed for extended testing in all of the studies. Children were tested daily, over periods of several weeks (in Experiments 1 and 3) and up to many months (in Experiments 2, 4, and 5). In all the studies, children responded consistently to the experimenter's modelling of target behaviours, without getting bored with the procedure. Thus data could be collected over many trials for each target behaviour. Most other developmental studies of imitation in young children collected very little data (usually within a single session, with as little as one response per target gesture) and had to rely on averaging over very large participant groups (e.g. Meltzoff 1988b). As discussed in Chapter 4, these group comparisons seldom incorporated adequate controls for non-imitative matching processes. In the present experiments, children's response data were collected over many trials for each target behaviour; individual children acted as their own controls, and replication over several children was used to establish generalisibility of the findings.
Chapter 5

Interpretations of the Matching Data

In published studies, children's apparently emergent matching of target behaviours has commonly been attributed to imitation. In the present experiments, the data were interpreted more cautiously.

As discussed above, children's apparently emergent matching of gestures and arbitrary actions in an experiment could be due to generalisation of trained matching. Thus target behaviours that have been directly trained as matches extra-experimentally may be emitted in response to the corresponding modelled behaviour in the experiment, apparently in the absence of direct training and external reinforcement. This is different from higher-order matching.

This distinction, not made in the experimental behaviour analytic literature so far, is very important. First, the two processes are functionally different (see Chapter 3). Second, generalisation of trained matching may, at best, result in matching of novel combinations of previously trained responses and in approximate matching of novel modelled behaviours that are similar to the trained ones. By contrast, higher-order matching should result in matching of a range of behaviours, including novel ones.

As a general rule, on the grounds of parsimony, children's unreinforced matching of target behaviours in the present experiments was assumed to be the result of generalisation of trained matching. In the experiments that employed participants who had learned some naming, the possibility
that some of the matching was verbally controlled was also discussed (see Chapter 3). The criteria for higher-order matching, such as children's self-correction over time and matching in the absence of external reinforcement and shaping, are discussed in each study and for each individual participant. Finally, the last two experiments were designed to test, directly, whether children under two years old show higher-order matching of gestures that have not been trained as matches.
CHAPTER 6

Experiment 1: Matching of Arbitrary Actions on Novel Objects in 9 - 15 Month Old Children

The aim of the experiment was to establish whether children under 15 months old can match simple object manipulations that have been arbitrarily paired with novel objects.

As discussed in the preceding chapters, several experimental studies have reported that children as young as nine months show higher rates of object-directed actions after the exposure to modelling of these actions, as compared with children who had not been exposed to such modelling. The authors attributed these (group) differences to imitation. However, it was argued that these studies failed to control and account for a multitude of non-imitative processes that could have resulted in children's matching of target actions. The present study was designed to address some of these issues.

Target Objects' Familiarity and Affordances

The earlier studies (e.g. Meltzoff, 1988a, Poulson & Kymississ, 1988) employed non-arbitrary action-object pairings: the target objects afforded very few specific actions; these afforded actions were modelled as
targets on the corresponding objects (Chairman, 1999). For example, Meltzoff (1988a) modelled the opening and closing action on a hinged wooden piece and the pressing action on a button set in a box. The target objects employed in this study were novel only in a trivial sense of having been made in the laboratory rather than purchased in a high-street shop. These target objects resembled certain conventional objects such as books and switches (respectively). Further, these target objects allowed for practically no other manipulations apart from the target ones.

As discussed in Chapter 4, children's apparent matching of these target actions was most likely due to extra-experimental learning the of the conventional actions trained to such objects, coupled with the socially enhanced stimulus control of the target objects and their components that occurred when they were handled in particular ways by the experimenter. For example, the children may have matched the "button pressing" target action because: (i) the experimenter's modelling produced the "finger-on-button" and "button-moving-in" stimuli that drew the children's attention to the relevant part of the target object (button vs. box that surrounded it); and (ii) the children already had pushing established as the conventional action that is performed with all buttons (and see Chairman & Huang, 2002, for further critique).

vonHofsten and Siddiqui (1993) reported that infants (6 and 12 months old) selectively matched some common actions but not others, depending on which objects the target actions were modelled with. In this study, mothers were instructed to model banging, shaking, rolling, and rubbing, with common toys (a fish, a rattle, a ball, and a doll). The target actions
were randomly paired with the toys. Infants (especially at 12 months) emitted many of the target actions with the appropriate toys prior to modelling (e.g. shook the rattle); overall, the effects of modelling were stronger for the older infants than for the younger ones. Across both groups, infants matched shaking when it was modelled with the rattle, but not when it was modelled with the doll; conversely, they matched rubbing when it was modelled with the doll, but not when it was modelled with the rattle. This experiment demonstrated that infants' matching was promoted by their familiarity with the target actions and the objects' affordances. Conversely, non-conventional pairing of common actions with common objects probably resulted in conflicting sources of control. For example, infants' history of play with dolls would have established rubbing as a strong response; maternal modelling of shaking may have been more effective in the presence of objects which did not evoke the competing, rubbing response.

The present study employed objects that were made, in our laboratory, of multi-coloured fabric and stuffed with polyester fibers. These target objects were therefore novel, but also resembled commonly available stuffed toys; their varied abstract shapes and colours made them clearly distinguishable to adults (see Figure 6.1). All the objects were soft to touch and of comparable sizes; they could be held and handled easily, with either one or two hands, by adults and children. No specific consequences of handling (such as sounds or changes of shape) distinguished between these target objects. They all afforded simple handling actions such as holding, squeezing, lifting, waving about, throwing, and poking.
Sets of three different target objects were chosen for each participant at random, from the pool of 21 available objects. The same target actions were used with all the participants and consisted of three simple object manipulations (waving, lifting, and touching the shoulder) that could be performed with any of the target objects. The complete set of target objects and the three target gestures are presented in Figure 6.1.

Target actions and objects were randomly paired for each participant; target actions were therefore arbitrary with respect to target objects. Thus, unlike the earlier studies, children could not show selective matching of target actions on the corresponding objects through generalisation of extra-experimental learning of object manipulations. Neither could they learn to perform the target actions on-line through the consequences of their handling of these objects, such as interesting sounds or changes in configuration that may occur when other objects are manipulated.

The present design can be seen as an improved version of the "dual-task" paradigm, advocated by Whitten and colleagues (e.g. Whiten, Custance, Gomez, Teixidor, & Bard, 1996), that was used in imitation experiments in non-human animals as a control for object affordances and on-line learning (see Chapter 2). The present study was the first to employ such a design with human infants. Experiment 1 consisted of two conditions; each is described in the following Method section.
Target actions (from left to right):
“object-to-shoulder”
“object-side-wave”
“object-up-move”

**Figure 6.1.** The set of three target actions that were arbitrarily paired with three different target objects for each child, and the entire set of 21 novel objects that were created for the present study. The objects in the set were of similar sizes: each object measured approximately 200mm x 100mm x 50 mm. The smaller sets of three target objects for each participant in Experiment 1 were chosen at random from this large set.
METHOD

Participants

All participants in the present and all the following studies were recruited from Tir na n'Og Childcare and Development Centre at the University of Wales, Bangor. Two girls and one boy participated in the present experiment. Children's gender and their ages at the start and the end of the experiment are presented in Table 6.1.1

<table>
<thead>
<tr>
<th>Child</th>
<th>Gender</th>
<th>Age at start (m-d)</th>
<th>Age at end (m-d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ann</td>
<td>Female</td>
<td>09 - 11</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Ria</td>
<td>Female</td>
<td>11 - 27</td>
<td>13 - 01</td>
</tr>
<tr>
<td>Jay</td>
<td>Male</td>
<td>14 - 04</td>
<td>15 - 02</td>
</tr>
</tbody>
</table>

1 In Experiments 1, 3, 4, and 5, in which *individual* participants' data are reported and discussed, all children are referred to by short first names. These short names were invented; children's real names were not used in order to preserve confidentiality. The writer as a reader felt that the discussion of what young children did in playful social contexts appeared unnecessarily abstract and strained when initials or numbers were used in place of first names. The participants are referred to as "children" in much of the text for the same reason.
The children attended the Nursery between three and five days per week, and were recruited by parental consent. According to the parents and the Nursery staff, all children were developing normally and had no known disabilities.

**Materials and Apparatus**

All the experimenter-participant interactions reported in the present and the following chapters took place in the purpose-built test rooms situated in Tir na n'Og Childcare and Development Centre at the University of Wales, Bangor.

The testing room used in the present study was furnished with a safe, padded infant chair. A small tray, attached to the front of the chair, provided a surface on which toys and objects could be placed. Bags made of fabric printed with toy and clown images were used to contain soft toys and target objects.

Two digital cameras were employed to record all interactions between children and the experimenter. The first camera was wall-mounted behind and above the infant seat and focussed on the experimenter; the second one was fixed on a wall above and behind the experimenter and focussed on the participant. A radio microphone was placed underneath the infant seat and used to record the sounds.

The outputs from the two cameras and the microphone were jointly incorporated in split-screen video recordings. JVC SR-VS10 video
recorders, with high quality slow motion and frame-by-frame viewing facilities, were used for recording and coding. All sessions could be monitored on-line by the Nursery staff from an audio-visual suite.

**Design**

A single-participant design, with replication across three children, and with multiple-baseline modelling across target gestures for each child, was employed in the present study.

Following Condition 1 (the familiarisation phase), 15 sessions of Condition 2 Probing were implemented for each child. Condition 2 Probing consisted of: (i) pre-modelling (Baseline 1) sessions, (ii) modelling sessions, and (iii) post-modelling (Baseline 2) sessions. Thus:

In Baseline 1, the experimenter presented the target objects without modelling the target actions in each of three sessions. The experimenter then presented modelling of the target action on the corresponding object for one object-action pair at a time, across three sessions for each such pair. In each three-session modelling block, while one target action was modelled on the corresponding target object, no target action was modelled for the other two objects; the latter were simply presented as in Baseline 1. The modelling of three target actions took nine sessions in all. Baseline measures of children's handling of the target objects prior to modelling of target actions were obtained over three sessions for the first target, over six sessions for the second target, and over nine sessions for the remaining target. In the last three sessions (Baseline 2) all objects were once again...
presented without modelling. Thus target objects were presented with modelling discontinued over nine sessions for the first target, over six sessions for the second target, and over three sessions for the third target.

Children's response data are presented in graphs and were analysed visually; statistical analyses were not used. The stages of the experiment are presented in Figure 6.2.

The present design was appropriate for establishing the following:

- Whether individual target objects evoked any specific handling behaviours, including target actions, prior to modelling of the target behaviours; such object-specific actions would be expected to emerge in the baseline sessions, either immediately or after prolonged exposure; thus the supposition that the novel target objects did not offer differential affordances, and did not evoke specific trained responses, could be tested.

- Whether there was a difference in children's performances of target actions on the corresponding target objects across baseline and sessions when modelling of these actions was presented; this could be established by comparing children's performances of target actions on the corresponding target objects before and during modelling sessions.

- Whether changes (if any) in children's handling of objects were due to the modelling of corresponding target actions or to continued exposure to
these objects. Sources of control of the children's target behaviours could be determined by comparing their handling of the objects for which modelling had been presented and their handling of the objects to which modelling had not yet been presented. The comparisons could also be made within target gestures, between children: all children were exposed to modelling of the same three target actions, but in a different order. For example, "placing target object on shoulder" was modelled as the first target action for Jay, as the second target action for Ria, and as the third target action for Ann.

- Whether children's matching of target actions was immediate, delayed, or both (i.e. it persisted over time); this could be established by recording children's manipulations of target objects that were offered to them immediately after modelling, and also in all the remaining sessions, after modelling was discontinued.

- Whether children's matching of target actions on the corresponding objects generalised to the other target objects; this could be established by recording whether or not a target action modelled in the presence of one object was performed by the children not only in the presence of the targeted (corresponding) object but also in the presence of one or both of the other objects.

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2 Since the multiple-baseline procedure necessarily involves passage of time, it is difficult to separate the effects of exposure to the target objects from possible extra-experimental effects, such as parental training of actions similar to the target ones in the home setting.
Chapter 6 Experiment 1

**Condition 1: Familiarisation**

Part 1: several weeks of play in the common room

Part 2: 3 sessions of give-and-take play with soft toys in test room

**Condition 2: Probing for Matching of Arbitrary Actions on Objects**

**Baseline 1: 3 Sessions**
Target objects were presented without modelling for all object/action pairs.

**Modelling of Target Actions: 3 x 3 sessions**
One target action was modelled at a time on the corresponding target object; modelling was presented over 3 sessions for each action/object pair.

The remaining objects were simply presented in these sessions, as in Baseline 1.

**Baseline 2: 3 Sessions**
Target objects were presented without modelling for all object/action pairs.

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**Figure 6.2.** The stages of Experiment 1.
Procedure

**Condition 1: Familiarisation**

In the first part of this condition the experimenter played with each child for several weeks in the playroom setting with other children and nurses present. This continued until the participants were happy, responsive, and comfortable with their new social partner. The familiarisation play was age-appropriate, with an emphasis on turn-taking and give-and-take games with toys. Throughout the weeks in which the experiment was conducted, the experimenter spent many additional hours with the participants, taking part daily in the Nursery routines (including feeding, outings, and indoor play activities). Thus the experimenter was treated by children and staff as one of the nurses, albeit more likely than most to engage in one-to-one play.

In the second part of this condition, three sessions of one-to-one play in the test room were conducted. The child was seated in a low infant chair, and the experimenter sat on the floor, facing the child.

The experimenter invited the child to play and proceeded to establish a give-and-take routine with toys. In her lap there was a closed bag containing five soft toys: an alligator, an elephant rattle, an Elmo (puppet show character) figure, an ambulance, and a pocketed picture book with a teddy attached. All toys were made of soft fabric and padded; they were bought from local high-street shops and then altered so that all noise-producing features were removed (e.g. bells from the rattle, "squeaks" and music.
buttons from other toys). Thus the toys resembled the target objects (that were presented in the next condition) in feel and size; however, they differed from the target objects in containing specific affordances, such as flaps that could be lifted, small bits that could be pushed, and holes that could be poked.

Over three consecutive sessions, the interaction was as follows: the experimenter pulled one toy at a time from the bag; she then turned it over in her hands slowly, several times, and offered it to the child. The experimenter never modelled any specific actions with the toys in this and the following condition. The child was encouraged to hand (not throw) the toy over when he or she had finished playing with it, and was praised for doing so; the experimenter then put the toy back in her bag and presented a new one to the child.

Each session lasted approximately 5 - 10 minutes. In both conditions of the experiment, a child was to be returned to the playroom if he or she cried or showed discomfort during testing. This never happened; all the scheduled sessions were completed without interruption. Children were tested daily, when they were available, alert, and happy to play.

**Condition 2: Probing for Matching of Arbitrary Actions**

All sessions started with play with toys; three or more toys were offered to the child. As in the previous condition, the experimenter pulled one toy at a time from her bag, handled it slowly while saying, "Look at this!" or, "What is this?" in order to attract the child's attention; she then offered
the toy to the child. The experimenter talked softly as the child handled the toy, to maintain the naturalistic joint-play context of the interaction, but avoided directing the child's play; for example, the experimenter said, "You like that one!" or, "What is Elmo doing?"

**Pre-Modelling Baseline (Baseline 1)**

The following took place in the first three sessions: after the toy play finished, the experimenter pulled the target objects out of her bag, one at a time, with handling and comments similar to those presented with the soft toys. Thus the experimenter slowly turned each object over in her hands (for 5 - 10 seconds) and said, "Look at this!" or, "I wonder what this is?" or, "Wow, wow, wow!" She then placed the target object on the tray in front of the infant seat and said, "You have a go!" or, "You have it!" or, "Here!"

The target objects were presented in randomised order, with one presentation per target object in each session. The child was allowed to handle each object for as long as he or she liked; this was seldom more than 10 - 15 seconds. If the child did not take hold of the object, the experimenter pointed at the object and asked the child to "have a go"; whenever the child threw or offered the object back without handling it first, the experimenter offered it back, up to three times for each object.
The experimenter did not attempt to direct the child's play in any way, except to urge him or her not to throw the objects away.\(^3\)

**Modelling: Multiple Baseline Across Target Actions**

Modelling of the target actions was presented in the next nine sessions. One target action was modelled at a time, over three sessions, on the corresponding target object; the remaining target objects were presented without modelling on these sessions, as described above.

The modelling was presented as follows: the experimenter pulled the target object from her bag and said, "Look at this!" She then modelled the corresponding target action slowly, and then repeated the action twice, making three presentations in all for each target action. When modelling the "object-to-shoulder" target action, the experimenter held the target object in her right hand, which she slowly moved across the midline so as to place the object on her left shoulder. When modelling the "object-side-wave" target action, the experimenter held the object in her right hand, then extended her right arm to the side, and moved it up and down slowly, twice. When modelling the "object-up-move" target action, the

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\(^3\) Yet they all threw on at least some trials. The experimenter had to pick the thrown objects up, either to return them to the bag, or to re-present them to the child. Thus the children’s object throwing was unintentionally reinforced by the experimenter's responses to this behaviour (especially with the youngest participant).
experimenter held the object in both her hands; she then lifted the object over her head, as far as possible, twice.

For all target actions, the experimenter looked at the target object while modelling, and then glanced at the child between repeating the action the second and the third time. She then offered the target object to the child, saying, "You have a go!" As in all other trials, if the child failed to engage with the object the experimenter offered it up to three times, saying, "Have another go!" or, "You have it!"

The child was not instructed to "imitate" or to "do as I do"; it was felt that such instructions may not be effective with the younger participants. All children's responses received unconditional smiling; whenever children offered the object back the experimenter said, "Ta!" (short for "thank you" commonly used in the Nursery).

**Post-Modelling Baseline (Baseline 2)**

The last three sessions were exactly the same as the first three sessions: all target objects were offered without modelling. Each session terminated after all three target objects were presented.

After the study was completed, parents were presented with videotapes that contained the recording of their child's performances. They were also given letters with comprehensive explanations of the procedure and the results of the study, and were encouraged to ask questions and comment on what they had seen. Children received small toys as presents.
Coding

The experimenter coded the children's behaviour by examining the videotapes of all the sessions. She viewed children's responses as many times as necessary to assign them to the pre-determined coding categories, and used slow-motion and frame-by-frame facilities to do so. The experimenter coded all the data twice; the second coding was done without the reference to the first codes. In the initial coding, the experimenter recorded all children's behaviours emitted during (i) the experimenter's handling and modelling of target actions, and (ii) the periods when children were presented with the target objects.

In the second round of coding, the children's behaviours were classified according to several different categories, which included the target actions, their components, and the actions that were similar to the target ones. Thus children's behaviours were coded as follows:

- Actions performed with objects vs. actions performed without objects; the latter were performed either (i) while the experimenter was handling an object and the child waited for his or her turn, or (ii) whenever an object was ignored and left on the tray, or (iii) immediately after an object was discarded (handed back or thrown).

- Actions performed bimanually vs. actions performed unimanually, with either the right or the left hand.

- Up/down arm movements or waving, performed in different locations (in front versus to side of body), with different magnitude (the low waves versus the high ones, that reached above head level), and that either
touched the tray (bouncing) or were performed entirely above it.

- Movements that touched or terminated on body parts, including: (i) the mouth, (ii) the backhand or lower arm, (iii) the shoulder, (iv) the temple, and (v) the head.

- Movements in which the hand(s) was (were) extended and then held still, either to the side of the body or up above the head.

The very brief movements with which the objects were thrown were not recorded as responses. The movements in which a hand holding the object clearly crossed the body midline were noted. Children's vocalisations were also noted.

The initial coding contained actions that were not classified in the second coding. These actions (e.g. pushing a tip of a target object and handing the object back) are commented on in the Results. The children's responses that were coded both times—target actions, their components, and actions similar to the target ones—are plotted in the Results.

*Intra-observer reliability* was computed across 30% of the data. Intra-observer agreement was good: 93% of actions were coded the same, with respect to the 20 different coding criteria listed above. The disagreements were small (e.g. a wave performed at about head level was coded as low in the first coding and as high in the second coding) and were resolved by re-examining the tapes.

A graduate researcher experienced in working with infants coded all the children's responses performed with the target objects (these included
target responses and their approximations; see Figures 6.12, 6.13, and 6.14 in Results). Inter-observer agreement was good: 97% of children's responses were coded the same. The disagreements were small and were resolved by discussion and re-examining the tapes.4

RESULTS

Condition 1: Familiarisation

As described in Method, the experimenter presented five soft toys in the last three sessions in Condition 1. These toys resembled the target objects (not presented in this Condition) in size and colouring. Unlike the target objects, the toys had specific affordances. Children's play was examined for object-specific actions that these toys, not available in the Nursery, evoked.

Jay, the oldest child, showed a wide range of actions on the toys; these were quite specific and tuned to the toys' individual affordances. Jay used his index finger to push any button-like bits of toys (e.g. Elmo's nose and

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4 An additional 7% of responses were coded by the experimenter but not the second observer; 5% of responses were coded by the second observer but not by the experimenter; the differences were in parsing of children's behaviours (e.g. a long wave was coded as two wave responses by one observer but not the other). These disagreements were never about children's correct matching responses.
aligator's eyes); he lifted flaps on the sides of the car and leafed through the pages of the book; he shook the elephant rattle and hugged it; he squeezed and poked toys and bits of toys which would normally have noise-making parts (that were removed). Jay also bounced the toys on his tray, lifted them and examined them, and often put them in his mouth. He pressed Elmo to his ear, as if it was a phone.

Ria's play repertoire was as varied. She shook the elephant rattle and pushed her hand through its hole; she pushed and twisted the protruding bits (e.g. Elmo's eyes) with her whole hand, index finger, and thumb; she hugged some of the toys, bounced them on the tray, and lifted them up. She placed the teddy on the book pockets (it is supposed to fit inside them) and jiggled the book from its string. She occasionally brought the toys to her mouth.

Ann showed a much smaller repertoire of toy directed actions, and no specific ones. She held the toys and poked at them briefly, waved them and bounced them on her tray. Her grip was always with the whole hand.

Jay and Ria often reached for the toys, and gave them back into the experimenter's extended hands. Ann did not reach (she waved her hands about instead) and did not return toys (she threw them or dropped them on virtually all her trials).

To summarise. Individual toys evoked a range of specific (afforded) actions, likely established with similar toys, for Jay and Ria; only a small amount of non-specific holding and poking was observed with the youngest
participant Ann. The children's interest in the toys rapidly diminished over sessions, possibly because their actions did not produce noises (as they would have done with the unmodified toys of this kind).

**Condition 2: Probing for Matching of Arbitrary Actions**

All Condition 2 sessions started with the toy play. In the second, main part of each session, the three target objects were offered to children, in a predetermined order (randomised for each session and for each child), one at a time.

In the first three sessions (Baseline 1) no modelling was presented. In Multiple Baseline Modelling of Target Actions, over the next three blocks of three sessions, one target action was modelled on the corresponding object in each block before the target object was given to the child; the remaining target objects were offered without modelling. The last three sessions (Baseline 2) were like the first three sessions: no modelling was presented on any of the target objects.

As noted in Method, children's response times were self-determined: they were allowed to interact with the target objects for as long as they wished. Most of their handling was very brief; on many trials they gave the objects back without handling them at all; in those trials the objects were represented up to two more times. On the few trials where the children did not return an object after half a minute or so, the experimenter asked for the object to be returned, and waited until the children complied with her request.
Children's baseline responses to target objects—their handling of objects prior to modelling—were recorded over three sessions for the first target object, over six sessions for the second target object, and over nine sessions for the third target object.

Children's handling of the experimental objects was markedly less varied than their toy-directed behaviours. All children held the objects and turned them in their hands, looked at them, waved them about or bounced them on the table, poked at them occasionally, and brought them to their mouth a few times. This was as expected: the objects were designed to offer as few as possible affordances for specific actions.

Jay was the only child who showed selective handling of one of his objects: his first object was conical in shape and had a tip which Jay pushed with his index finger and gripped with his index and thumb; the remaining objects were gripped with the whole hand(s).

Overall, children did not show much interest in the target objects; they handled them briefly if at all, and offered them back to the experimenter as soon as they received them, on most trials. The youngest participant (Ann) threw the objects away immediately on most of her trials. The children did not produce any entirely correct target actions in their baseline sessions, although some actions similar to the target ones were noted (as described in the following paragraphs).
The same three target actions: "object-to-shoulder", "object-side-wave", and "object-up-move", were modelled to each child, but in a different order and on different objects across children. The effects of modelling of target actions on children's handling of target objects, and the remaining objects which were not targeted, are reported next.

"Object-To-Shoulder" Target Action

The "object-to-shoulder" target action was modelled as the first target action for Jay, as the second target action for Ria, and as the third target action for Ann. When modelling, the experimenter held the target object in her right hand which she moved across her body midline to place the object on her left shoulder.

The children never performed this target action correctly on any of their sessions. Figures 6.3, 6.4, and 6.5 show records of children's object-to-body responses that were in some respects similar to the "object-to-shoulder" target action. Thus:

- **Bimanual touches to incorrect body parts** (e.g. mouth, head) were recorded whenever children brought an object to touch body parts other than the shoulder and used both hands to do so; their hands did not cross body midline.

- **Unimanual ipsilateral touches to incorrect body parts** were recorded whenever children brought an object to touch body parts other than the
shoulder and used one hand to do so, but their hand did not cross body midline.

- **Unimanual contralateral touches to incorrect body parts** were recorded whenever children brought an object to touch body parts other than the shoulder and used one hand to do so; their hand crossed body midline.

- **Unimanual touches to ipsilateral shoulder** were recorded whenever children brought an object to touch the shoulder and used one hand to do so, but their hand did not cross body midline.
Figures 6.3, 6.4, and 6.5. "Object-to-shoulder" target action: children's object-to-body responses that were in some respects similar to this target action. The following actions are plotted:

1. Bimanual touches to incorrect body parts (green squares).

2. Unimanual ipsilateral touches to incorrect body parts (blue squares).

3. Unimanual contralateral touches to incorrect body parts (yellow squares).

4. Unimanual touches to ipsilateral shoulder (red squares).

Children's actions are plotted for all objects. Target actions that were paired with the individual target objects are illustrated in the left side of the graphs. "Object-to-shoulder" target action and its corresponding target object are shaded grey.

The main part of each graph shows children's responses across 15 Condition 2 probing sessions, including 3 Baseline 1 sessions, 9 Multiple Baseline Modelling of Target Actions sessions, and 3 Baseline 2 sessions. The three sessions in which modelling of the "object-to-shoulder" target action was presented are shaded grey. Children's responses, represented by coloured squares, are plotted in the graphs bottom-to-top in the order in which they were emitted in each session.
Figure 6.3. "Object-to-shoulder" (target action 1): responses for Participant Jay. Modelling sessions (4, 5, and 6) are shaded in the top graph.
Figure 6.4. “Object-to-shoulder” (target action 2): responses for Participant Ria. Modelling sessions (7, 8, and 9) are shaded in the middle graph.
Figure 6.5. "Object-to-shoulder" (target action 3): responses for Participant Ann. Modelling sessions (10, 11, and 12) are shaded in the bottom graph.
Figure 6.3 shows that Jay brought the first object to touch body parts other than shoulder four times in Baseline 1 (Sessions 1 - 3), before modelling of the "object-to-shoulder" target action was presented with this object. These baseline touches were performed with both hands twice and with his right hand twice; all touches were to his mouth.

In Sessions 4 - 6, in which the "object-to-shoulder" target action was modelled on the first object, Jay did not emit any hand-to-body responses. However, he started placing the target object on body parts from Session 7, after modelling for the latter object was discontinued. In Session 7, he held the target object in his left hand and touched his left shoulder, without crossing his body midline; he then moved the object across his body midline but placed it on the back of his right hand; finally, he touched his left temple with the object, without crossing his body midline. In Sessions 8 - 12, Jay consistently held the target object in his left hand and crossed his body midline to place the object on the back of his right hand; in Session 10 he also held the target object in his right hand and crossed his body midline to touch his left palm and lower arm; he finally brought the target object to his mouth with both hands, twice. In Session 13, Jay held the target object in his left hand and touched his left temple. No object-to-body touches were recorded in Sessions 14 and 15.

Object-to-body touches were never recorded for Jay's second object, and only one right-handed touch to mouth was recorded in Session 6 for the third object. Thus his most frequent action with the first target object was never used with the remaining objects; however, in Session 11, Jay held
one of the toys in his left hand and placed it twice on the back of his right hand, crossing his body midline, in much the same was as he handled the first target object. Further, Jay performed several actions in which he held an object or toy, then crossed his body midline and his other arm that was resting on the tray, but released the object or toy over the rim of the tray rather than placing it on a body part. Finally, in Session 4, Jay performed one very clear "hand-to-shoulder" action, but without an object: his left hand touched his right shoulder, crossing his body midline, to adjust the safety harness strap.

To summarise. Modelling of "object-to-shoulder" target action appeared to have had an effect on Jay's handling of the corresponding target object; this effect was found only after modelling was discontinued and was fairly specific to the target object. Although Jay emitted the exact, correct target action configuration without an object once, all his target object-directed responses were approximations. Thus Jay emitted one touch to the correct body part but with an incorrect (ipsilateral) movement, a few touches to near body parts (temple) with incorrect (ipsilateral) movements, and several contralateral movements but with touches to incorrect body parts (mostly the back of his hand). The contralateral touches to the back of his hand were also emitted to one of the toys.

Figures 6.4 and 6.5 show that the remaining two participants, Ria and Ann, never emitted any object-to-body actions in which a hand holding an object crossed the body midline; nor did they ever touch a shoulder. Ria and Ann brought the objects to their mouth on a few sessions each, with one hand and with both hands; Ria also touched her head. Modelling of the
"object-to-shoulder" target action did not change Ria's and Ann's responding with any of the objects.

"Object-Side-Wave" Target Action

The "object-side-wave" target action was modelled as the first target action for Ria and as the second target action for Jay and Ann. When modelling, the experimenter held the target object in her right hand and extended her right arm to the side; she then produced slow and large waving (up/down) movements.

Jay and Ria produced the correct target action configurations with some of their objects, on some of their trials; the remaining child, Ann, never produced a correct target configuration. Figures 6.6, 6.7, and 6.8 show records of children's "object-side-wave" target responses and of responses that were in some respects similar to the "object-side-wave" target action. Thus:

- **Bimanual waving** was recorded whenever children held an object and waved it up/down, but used both hands to do so.

- **Bimanual waving without object** was recorded whenever children moved both hands up/down but did so without holding an object.

- **Unimanual frontal waving** was recorded whenever children held an object in one hand and waved it up/down, but performed this movement in front rather than to side of their body.
- **Unimanual frontal waving without object** was recorded whenever children moved one hand up/down, but performed this movement in front rather than to side of their body, and did so without holding an object.

- **Hand extended to side without waving** was recorded whenever children held an object to side of their body but did not perform up/down waving.

- **Mirror (left-handed) side waving** was recorded whenever children emitted the correct target response configuration (held an object to side of body and waved) but used their left hand to do so.

- **Mirror (left-handed) side waving without object** was recorded whenever children emitted the correct target response configuration (extended an arm out to side of body and waved) but used their left hand, and did not hold an object.

- **Correct (right-handed) side waving** was recorded whenever children emitted the correct target response configuration (held an object to side of body and waved) and used their right hand to do so.

- **Correct (right-handed) side waving without object** was recorded whenever children emitted the correct target response configuration (extended an arm out to side of body and waved) and used their right hand, but did not hold an object.
Figures 6.6, 6.7, and 6.8. "Object-side-wave" target action: children's "object-side-wave" responses, and their other responses that were in some respects similar to this target action. The following actions are plotted:

1. Bimanual waving (green squares).
2. Bimanual waving without object (green striped squares).
3. Unimanual frontal waving (blue squares).
4. Unimanual frontal waving without object (blue striped squares).
5. Hand extended to side without waving (yellow squares).
6. Mirror (left-handed) side waving (red squares).
7. Mirror (left-handed) side waving without object (red striped squares).
8. Correct (right-handed) side waving (brown squares).
9. Correct (right-handed) side waving without object (brown striped squares).

Children's actions are plotted for all objects. Target actions that were paired with the individual target objects are illustrated in the left side of the graphs. "Object-side-wave" target action and its corresponding target object are shaded grey.

The main part of each graph shows children's responses across 15 Condition 2 probing sessions, including 3 Baseline 1 sessions, 9 Multiple Baseline Modelling of Target Actions sessions, and 3 Baseline 2 sessions. The three sessions in which modelling of "object-side-wave" target action was presented are shaded grey. Children's responses, represented by coloured squares, are plotted in the graphs bottom-to-top, in the order in which they were emitted in each session.
**Figure 6.6.** "Object-side-wave" (target action 2): responses for Participant Jay. Modelling sessions (7, 8, and 9) are shaded in the middle graph.
Figure 6.7. "Object-side-wave" (target action 1): responses for Participant Ria. Modelling sessions (4, 5, and 6) are shaded in the top graph.
Figure 6.8. "Object-side-wave" (target action 2); responses for Participant Ann. Modelling sessions (7, 8, and 9) are shaded in the middle graph.
Figure 6.6 shows that "object-side-wave" was the second target action for Jay. In the Sessions 1 - 6, before modelling of the "object-side-wave" target action was presented, Jay emitted no waving or extending an object to side of body with his second object. In Sessions 7 - 9, in which modelling was presented, Jay responded by holding the corresponding target object in his right hand and waving it in front of his body. Three such responses were emitted in Session 10, after modelling of "object-side-wave" was discontinued, and one more response was emitted in Session 11. In Sessions 13 and 14, Jay waved without holding the target object: once with both hands, twice with one hand in front, and once with one hand to the side of his body.

Across the sessions for the remaining two objects, Jay showed no waving, with or without holding an object, until Session 11. Extending his hand (mostly left) to the side without waving was a frequent response with the first object and appeared once with the third object, but was never performed with the target object.

In Sessions 11, 12, 14, and 15, Jay emitted unimanual frontal waves with his third object; and in Session 14 two such responses were emitted with his first object. Jay emitted several waves without holding an object: bimanual waves were emitted once in Session 13 (first object), and once in Session 14 (third object); four unimanual frontal waves were emitted in Sessions 13 and 15 (first object). Jay's actions on the first object included three correct "object-side-wave" configurations that were performed with the left (mirror) hand, in Sessions 11 and 13.
To summarise. Jay never emitted waving responses (with or without an object) to any of his objects until modelling of "object-side-wave" target action was presented. Modelling affected Jay's responding to the corresponding target object immediately: he emitted approximations to this target action, frontal waving, to this object over several sessions. After modelling was discontinued, these responses were emitted with the remaining two target objects also; waving without holding an object was also emitted in these later trials, across all objects. In the later sessions, Jay emitted the correct "object-side-wave" response configuration with his left (mirror) hand three times with his first object, but never with the appropriate target object. Jay emitted a single left-handed (mirror) side wave when presented with his target object in Session 14, but did not hold the object as he did so.

Figure 6.7 shows that the "object-side-wave" was the first target action for Ria. Ria emitted frontal waving with or without holding an object on Sessions 1 - 3, across her first and second objects, before "object-side-wave" target action was modelled with her first object. During Sessions 1 - 3, she also extended her arm to the side without waving with her first and second objects.

Ria's responding to the target object did not appear to be affected by modelling of the corresponding target action: unimanual waving was recorded for all three of her objects throughout the remaining sessions. Ria emitted the correct "object-side-wave" response configurations with her right (correct) and her left (mirror) hands, and emitted one side wave without holding an object (first object, Session 8). The first of these
responses was recorded with her third object (Session 5) and not with the target object on which "object-side-wave" target action was modelled. Across the later sessions, after modelling of the target action was discontinued, Ria emitted unimanual side waves to the target object six times, and to her second object twice.

To summarise. Frontal waving, with one or two hands, with or without holding and object, was a frequent action throughout all sessions and across all objects for Ria. The correct "object-side-wave" configurations, performed with the right (correct) and the left (mirror) hand appeared in the later sessions; these responses were not emitted immediately in response to modelling of the "object-side-wave" target action on the corresponding target object, nor were they confined to the appropriate target object.

Figure 6.8 shows that "object-side-wave" was the second target action for Ann; she never produced a correct response. The figure shows that Ann waved in front but without holding an object on many of her sessions, and across all of her objects; most of these responses were emitted while the experimenter was handling and showing her objects. Ann held her second object to the side without waving on three sessions (Sessions 3 - 5), prior to modelling of the "object-side-wave" target action on this object; she also performed this action once on her first object (in Session 8). Ann only emitted two frontal waving responses, both on her first object; one of these was bimanual (Session 4) and the other was unimanual (Session 8).

Ann's responding did not change after modelling of "object-side-wave"
target action was presented with her second object. Although she emitted a frontal wave holding her first object she never did so with her target object, either during or after "object-side-wave" target action was modelled. Although she extended her second object to the side without waving on three baseline sessions, she never emitted this response during or after modelling of the target action with this object.

"Object-Up-Move" Target Action

"Object-up-move" target action was modelled as the first target action for Ann and as the third target action for Jay and Ria. When modelling, the experimenter held the target object in both her hands and lifted it well over her head, while looking up.

Figures 6.9, 6.10, and 6.11 show records of the children's waving and lifting responses that were in some respects similar to the "object-up-move" target action. Thus:

- **Small bimanual moves** were recorded whenever the children held an object with both hands and either placed it on body parts, or bounced it on the table, or waved it a little, without reaching above head level.

- **Small bimanual moves without object** were recorded whenever the children moved both hands at the same time to either tap the table, or to wave a little, without reaching above head level; they did so without holding an object.
• Tall unimanual waving was recorded whenever the children held an object with one hand and waved strongly, reaching above head level.

• Tall unimanual waving without object was recorded whenever the children waved strongly with one hand, reaching above head level; they did so without holding an object.

• Unimanual lifting was recorded whenever the children held an object in one hand and lifted it well above head level.

• Unimanual lifting without object was recorded whenever the children lifted one hand well above head level, without holding an object.

• Tall bimanual waving was recorded whenever the children held an object with both hands and waved strongly, reaching above head level.

• Tall bimanual waving without object was recorded whenever the children waved strongly with both hands, reaching above head level; they did so without holding an object.

• Bimanual lifting without object was recorded whenever the children lifted both hands well above head level, without holding an object.
Figures 6.9, 6.10, and 6.11. "Object-up-move" target action: children's responses that were in some respects similar to this target action. The following actions are plotted:

1. Small bimanual moves (green squares).
2. Small bimanual moves without object (striped green squares).
3. Tall unimanual waving (blue squares).
4. Tall unimanual waving without object (striped blue squares).
5. Unimanual lifting (yellow squares).
6. Unimanual lifting without object (striped yellow squares).
7. Tall bimanual waving (red squares).
8. Tall bimanual waving without object (striped red squares).

Children's actions are plotted for all objects. Target actions that were paired with the individual target objects are illustrated in the left side of the graphs. "Object-up-move" target action and its corresponding target object are shaded grey.

The main part of each graph shows children's responses across 15 Condition 2 probing sessions, including 3 Baseline 1 sessions, 9 Multiple Baseline Modelling of Target Actions sessions, and 3 Baseline 2 sessions. The three sessions in which modelling of "object-up-move" target action was presented are shaded grey. Children's responses, represented by coloured squares, are plotted in the graphs bottom-to-top in the order in which they were emitted in each session.
Figure 6.9. "Object-up-move" (target action 3): responses for Participant Jay. Modelling sessions (10, 11, and 12) are shaded in the bottom graph.
**Figure 6.10.** "Object-up-move" (target action 3): responses for Participant Ria. Modelling sessions (10, 11, and 12) are shaded in the bottom graph.
Figure 6.11. “Object-up-move” (target action 1): responses for Participant Ann. Modelling sessions (4, 5, and 6) are shaded in the top graph.
Figure 6.9 shows that Jay lifted his third object unimanually twice (in Sessions 1 and 7) before "object-up-move" target action was modelled on this object in Sessions 10 - 12. In the modelling sessions, Jay lifted the target object twice with one hand, and twice he emitted tall waves, also with one hand. After modelling of "object-up-move" target action was discontinued, Jay emitted two tall unimanual waves in Session 14, one of which was performed without holding the target object.

Jay's responses to the remaining two objects, across sessions, were similar to his responses to the target object: unimanual lifting was done seven times with the first object and four times with the second object. Jay performed one tall unimanual wave with his first object, and six such responses with the second object; one further unimanual tall wave was done without holding the object (second object, Session 14).

Jay emitted bimanual responses to his first and second object, but not to his third (target) object; there were four small moves with the first object (bringing it to mouth) and two small bimanual moves without object (low waving), on Session 13, one each to the first and the second object.

Jay turned his face up and looked up, just as the experimenter did when modelling the "object-up-move" target action, twice in Session 11 with his second object, and six times in Sessions 10, 11, 12, and 14 with his third, target object.

Overall, it appeared that "object-up-move" target action was matched by
Jay as unimanual lifting or tall waving, accompanied by looking up. These actions were also emitted with the remaining two objects, and before "object-up-move" target action was modelled; looking up also appeared twice with Jay's responses on his second object. Bimanual actions were never emitted with the target object, but appeared with the remaining two objects.

Figure 6.10 shows that the "object-up-move" was modelled as Ria's third target action. Ria emitted varied lifting and waving responses to all her objects. She emitted tall bimanual waving—which contained a correct "object-up-move" configuration—once with her first object, but never with her third, target object. Ria also emitted tall bimanual waving and bimanual lifting without an object three times (Sessions 7, 11, and 15) to her first and her second object, but never to her target object.

Ria responded to modelling of "object-up-move" target action by lifting or waving the target object unimanually on two modelling sessions (10 and 11), and by small bimanual moves (touches to forehead and mouth) on Session 12. The latter action was not previously performed with the target object, but was emitted to the remaining two objects.

Ria looked up on many occasions; these included: with her first object on Session 5, 11, and 12; with her second object on Session 9; and with her target object on Sessions 4 and 11. Modelling the of "object-up-move" target action did not result in more frequent looking up with the target object.

Overall, Ria showed high frequencies of tall unimanual waving and of
unimanual lifting across all her objects; she also performed these actions without holding an object across sessions. Modelling of the "object-up-move" target action did not appear to affect Ria's performance with the target object much. Although some good (bimanual) approximations to the target action were emitted to her first and second objects, these actions were not emitted to the target object.

Figure 6.11 shows that "object-up-move" was the first target action for Ann. Across all objects, Ann only emitted a single unimanual lifting action with her third object in Sessions 1 - 3, before "object-up-move" was modelled with her first object. In the following sessions, Ann emitted many small bimanual moves, mostly tapping the tray while the experimenter was handling the objects, across all three objects.

Across all objects, Ann emitted tall bimanual waving and bimanual lifting without an object, after modelling of "object-up-move" on her first object was discontinued (in Sessions 7, 9, 11, 13, 14, and 15). Again, most of these responses were emitted while the experimenter was showing the objects. In the second half of sessions, Ann also emitted unimanual lifting with and without objects, to all objects. She looked up on Session 1 (third object) and on Session 14 (once for target object, twice to second object, twice to third object).

Overall, Ann did not reliably respond to modelling of "object-up-move" target action. It is possible that this modelling resulted in the appearance of small bimanual movements (the fewest of which were emitted with the target object). Tall waving and unimanual lifting actions were emitted to
all objects, especially in later sessions; however, these actions were never emitted in the sessions in which the "object-up-move" target action was modelled.

**A Summary of Children's Correct and Approximate Responses**

Children's data are summarised in Figures 6.12, 6.13, and 6.14; these show the percentages of sessions in which: (i) correct and mirror responses, which both contained correct response configurations performed with either the right (correct) or the left (mirror) hand; and (ii) approximations to these responses, were emitted to target objects, and to the remaining two objects, across individual children. The percentages are plotted for three target actions and for children's responses emitted in (i) baseline sessions (prior to modelling of target actions), (ii) modelling sessions, and (iii) the remaining sessions (in which modelling was discontinued).

Only children's actions performed with objects were counted; the approximations were a subset of all actions plotted in Figures 6.3 - 6.11, and consisted of:

- For "object-to shoulder" target action: (i) contralateral touches to body parts other than shoulder and (ii) ipsilateral touches to shoulder. These in which the responses where the movement path was correct or in which correct body part was touched, but not both.

- For "object-side-wave" target action: (i) all waving, performed in front or to the side of body, with one or two hands, and (ii) extending a hand to side of body without waving. Waving in front contained correct
movement but was not performed on correct location; extending hand to side was performed at a correct location but did not include the correct movement; waving to side was entirely correct but was seldom performed (by Ria and Jay only).

- for "object-up-move" target action: (i) tall waving which reached overhead, performed with one or two hands, (ii) all lifting overhead, performed with one or two hands, and (iii) all small bimanual moves. Modelling of this gesture included two repetitions of bimanual lifting; thus unimanual tall waving and unimanual lifting were both similar to the modelled action, although the movement was performed with one instead of two hands; in small bimanual moves both hands held the object but did not lift it overhead. Tall bimanual waving and tall bimanual lifting were both correct matches; only the former was emitted, once, by one child (Ria).

This level of coding corresponds to those usually employed in developmental studies, in which children's data were coded categorically (i.e. whether the target response was performed or not in each trial; see Meltzoff, 1988a) and where a range of approximations to correct responses were often coded as correct (e.g. Gleissner et al, 2000; and see Chapter 8).

Figure 6.12 shows that Jay emitted approximations to target responses on a larger proportion of sessions after modelling was presented than prior to modelling, across all target object/action pairs. The effect of modelling was immediate for "object-side-wave" and "object-up-move" target actions, and delayed for "object-to-shoulder" target action. Further, Jay's percentages of sessions with target approximations remained higher after modelling was
discontinued than they were in the baselines, for all target objects. Jay's performance of target approximations across the remaining pairs of objects was unaffected by modelling for the "object-to-shoulder" target action.

After modelling of the remaining two target actions, the approximations to target responses were emitted more frequently to the remaining pairs of objects (on which these actions were not modelled) as well as to the target objects (on which these actions were modelled).

Figure 6.12. Percentages of sessions in which correct responses (blue bars) and approximations to these responses (red bars) were emitted to target objects, and to the remaining two objects, for Participant Jay. The percentages are plotted for three target actions and for Jay's responses emitted in: baseline sessions ("BAS"), modelling sessions ("MOD"), and the remaining sessions after modelling was discontinued ("AFT").

Figure 6.13 shows that Ria never emitted approximations to "object-to-shoulder" target actions either to the corresponding object or to the remaining two objects; modelling of this target action had no effect. In
contrast, Ria emitted approximations to "object-side-wave" target action on all her baseline trials with the corresponding target object. During and after modelling of this target action percentages of trials with correct response approximations actually decreased with the target object. At the same time, the percentages increased during and after modelling with the remaining two objects (on which this target action was not modelled). The percentage of sessions with approximations to "object-up-move" target action increased during modelling for the corresponding target object and then decreased after modelling was discontinued; a large increase in performance of the “object-up-move” action during and after modelling also occurred to the remaining two objects.

Figure 6.13. Percentages of sessions in which correct responses (blue bars) and approximations to these responses (red bars) were emitted to target objects, and to the remaining two objects, for Participant Ria. The percentages are plotted for three target actions and for Ria’s responses emitted in: baseline sessions (“BAS”), modelling sessions (“MOD”), and the remaining sessions after modelling was discontinued (“AFT”).
Figure 6.14 shows that Ann seldom emitted any approximations to the target actions. Her responses to the corresponding target objects and to the remaining two objects were not affected by modelling of "object-to-shoulder" target action. For "object-side-wave" target action, the baseline percentage of approximations actually dropped during modelling for the corresponding target object. Modelling of "object-up-move" seemed to produce a slight increase in her percentage of approximations on the corresponding target object, but not for the remaining two objects.

**Figure 6.14.** Percentages of sessions in which approximations to correct responses (red bars) were emitted to target objects, and to the remaining two objects, for Participant Ann. The percentages are plotted for three target actions and for Ann's responses emitted in: baseline sessions ("BAS"), modelling sessions ("MOD"), and the remaining sessions after modelling was discontinued ("AFT").
DISCUSSION

The children in the present study seldom produced the entirely correct target responses before, during, or after exposure to modelling of the three target actions, on any of their objects. Across all children and all target objects, only Ria produced one of her target responses ("object-side-waves") on the corresponding target object, and did so only after modelling of this target action was discontinued. Thus the overall result of the present study is that children did not show correct matching of three simple object manipulations that were modelled on novel objects.

As discussed in Chapter 4, Meltzoff and his colleagues claimed that infants as young as nine months show imitation of object-directed actions through active inter-model mapping of behaviours of others that they see and their own behaviours that they monitor and adjust through proprioception (e.g. Meltzoff & Moore, 1992). This ability to match the responses to the actions of others was said to be present at birth and further develop during infancy. The present data do not support this account: children as old as 15 months did not show correct matching of target actions that were within their motor abilities, and that were in no obvious way more difficult to perform than the actions used by Meltzoff and his colleagues. Thus:

- All children placed objects on body parts (mouth, back of hand, temple, palm, arm, and shoulder for Jay, who also placed the Elmo toy on his ear; mouth and head for Ria, who also often placed a teddy on its pocket when handling the book toy; mouth and head for Ann). All children performed
some contralateral movements in which a hand clearly crossed the body midline (Jay to place an object and a toy on back of his hand, palm, and lower arm; all children to throw, push, or drop objects and toys across the tray). Yet no child performed a correct contralateral "object-to-shoulder" response. This target action may have been novel for the participants, but likely not beyond their motor abilities, especially for the two older children—Jay effortlessly touched his contralateral shoulder to adjust a safety harness strap in one of the sessions. Meltzoff (1988b) claimed that infants perform entirely novel acts after seeing them done once; this was clearly not so for the "object-to-shoulder" target action in the present study, even though many modelling and response opportunities were presented. According to Meltzoff's active inter-model mapping account, infants adjust their own responses until they match the organ relations of the seen models. In the present study Jay placed the target object on his shoulder (with an ipsilateral movement) but then "corrected" himself and proceeded to place the target object on the back of his hand over many trials; touching his shoulder was never emitted again. This is not consistent with Meltzoff's predictions, because Jay's later responses were less, not more, similar to the modelled target action.\(^5\)

- All children waved, with and without holding an object, mostly in front of their body. All children extended one or both of their hands to side of

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\(^5\) Jay's responses are also inconsistent with the goal theory of imitation of Bekkering and colleagues (Bekkering, Wolshlager, & Gattis, 2000), discussed at length in Chapter 8, which claims that touching a correct body part is always perceived by children as the dominant goal of an action.
their body while holding an object. Yet no child consistently matched the "object-side-wave" target action. Jay emitted three "object-side-wave" responses with an object that was not used for modelling of this target action, but never with the target object: he responded to modelling of "object-side-wave" by waving the target object in front. Ria emitted nine "object-side-wave" responses to all three of her objects, yet never emitted this action on the corresponding target objects in the trials where modelling was presented. Further, Ann extended her hand holding the target object to side several times before modelling of "object-side-wave" was presented, and waved an object other than the target one, but never emitted these responses on the target object in the trials where modelling of "object-side-wave" was presented, or in her later trials. Thus "object-side-wave" was within children's motor abilities and certainly not a novel action for the older two children, who still did not match it correctly when it was modelled to them. Therefore all children's responses to modelling of "object-side-wave" target action were inconsistent with Meltzoff's active intermodal mapping account.

- All children held and moved objects and toys with two hands. All children emitted high waves that reached overhead, with and without holding objects and toys. All children lifted their hands with or without holding objects and toys. Ria and Ann emitted tall bimanual waving without objects, and Ria emitted a correct "object-up-move" response (a tall bimanual wave with an object) prior to modelling of the "object-up-move" target action. Jay lifted one of the toys (a car) above head level while holding it with both hands. Thus this target action was within children's motor abilities, and not novel. Yet no child emitted a correct,
bimanual "object-up-move" target action with the corresponding target object in response to modelling. Once again, this is inconsistent with Meltzoff's active intermodal mapping account.

While no child emitted a correct target action with the corresponding target object after seeing it modelled, all children emitted many of the actions that Meltzoff and his colleagues (e.g. Meltzoff 1988a; and see Chapter 4) used as targets in their experiments, in play with toys that afforded these actions. Thus all children pressed button-like parts; Jay and Ria opened and closed the book; Ria placed the teddy on its belonging pocket and jiggled the book from its string. As argued in Chapter 4 and the introduction to the present chapter, Meltzoff's data overestimated children's imitative abilities by using object/action pairs that afforded target actions and no other manipulations, and by using objects that were similar to common toys and that evoked well-trained responses.

**Higher-Order Matching**

As discussed in Chapters 3 and 5, higher-order matching refers to children's ability to match a range of behaviours, including novel ones, without external (social) reinforcement for doing so. Children's data in the present study did not show evidence of higher-order matching: children did not match target actions which were within their motor abilities and were emitted with non-target objects, toys, and without objects (as gestures). Children's performances did not improve over time, as would have been expected if similarity between the experimenter's and their own
behaviour was reinforcing the responses that achieved such similarity.

However, the present data did not conclusively demonstrate that children had no higher-order matching abilities. This is because:

- The experimenter had no knowledge of individual children's trained matching repertoires, which is necessary for discerning which of the children's responses were the result of generalisation of trained matching and which (if any) were never directly trained as matches.

- The experimenter never reinforced any of their correct matching responses, although such reinforcement may be necessary to support the secondary reinforcing properties of similarity (or parity).

As discussed in Chapter 3, several behaviour-analytic studies reported that older children matched a range of behaviours as long as the experimenter presented reinforcement for correct matching of a subset of these behaviours; the matching diminished or ceased after such reinforcement was discontinued (e.g. Baer & Deguchi, 1965). However, other studies with younger children and infants, including virtually all cognitive developmental studies (e.g. Meltzoff 1988a; and see Chapter 4), reported that children matched modelled behaviours without external reinforcement for doing so.

The experimenter in the present study was a familiar social partner; she produced social reinforcement for playing with toys (comments and smiling) and unconditional reinforcement (smiling) for all object-directed behaviours. As discussed in the next paragraphs, her modelling of target actions seemed to affect some of the children's responses; presumably,
children generalised their responding to various caregivers, including the experimenter. However, it is likely that the children's matching in an experiment would be enhanced if reinforcement was produced for at least a subset of their correct matching responses.

The present data can be compared to that from other developmental studies with infants of similar ages in which deliberate differential reinforcement for correct matching was not given. However, no strong conclusions about children's higher-order matching abilities can be drawn from the present findings. In the remaining experiments (see Chapters 7, 8, 9, and 10), correct matching of a subset of all modelled behaviours was directly trained and reinforced throughout the procedure for each individual participant.

Changes in Children's Responses Over Sessions

As shown in the Results, modelling of the three target actions did seem to affect some of children's responses to some of the objects. Ann's responses seemed unaffected by modelling; some changes were observed for two target actions for Ria, and for all target actions for the oldest child, Jay. Thus:

- Figures 6.12 and 6.13 show that Jay and Ria emitted "object-side-wave" responses only during sessions in which modelling of this target action was presented, and in the remaining sessions. However, these responses were emitted to the corresponding target objects less frequently than to
the other objects (on which modelling of "object-side-wave" target action was not presented).

- Jay and Ria emitted approximations to the "object-up-move" responses more frequently during modelling of this target action than before or after modelling. However, the effect was seen not only with the target objects but with the remaining objects.

- Jay emitted approximations to the "object-to-shoulder" target action on the corresponding object but not with the remaining objects (although similar responses were also noted with one of the toys). These approximations were not emitted until modelling of the "object-to-shoulder" target action was discontinued, but appeared consistently over many trials thereafter.

- Jay emitted approximations to the "object-side-wave" target response on the corresponding target object only during and after modelling of this target action, but not before. However, the effect is difficult to evaluate against a rising incidence of similar responses that were emitted on the remaining objects (that were not targeted by modelling of this target action).

- Ria performed "object-side-wave" approximations on her target object on all baseline trials; these responses actually declined during and after modelling sessions. However, "object-side-wave" approximations were emitted more frequently during the modelling sessions with her remaining objects (that were not targeted by modelling of this target
action).

**Extra-Experimental Variables**

Whenever an effect of an intervention is seen not just for targeted behaviours (with targeted objects in this case), but across all the remaining behaviours (with untargeted objects in this case), it is possible that the effect was in fact not due to the intervention at all, but was caused instead by external, unmanipulated and uncontrolled, variables. Thus, in the present study, it could be argued that children emitted more target response approximations across all of their objects not because of modelling of the target actions on the corresponding objects, but for reasons of prolonged exposure to the objects and extra-experimental training of target behaviours with other, similar objects.

However, this explanation seems unlikely because in three out of four cases where the children's responses changed across sessions for objects that were not targeted with modelling of a target action, the patterns showed the highest incidence of target action approximations during modelling sessions, as compared to before and after modelling. By contrast, increases in target behaviour approximations due to variables other than modelling of target actions would likely be gradual and not linked to the presence or absence of modelling; this was the case across only one set of behaviours, for one child. A more likely explanation for the observed changes is that the effects of modelling of target actions on children's target response approximations, in at least three cases, generalised to the remaining
objects that were not targeted by modelling of the corresponding target action.

**Social Stimulus Enhancement**

It is possible that some of the effects of modelling on children's responses to all objects were due to social stimulus enhancement. As discussed in Chapter 2, this term refers to an overall increase in attention to and handling of an object that resulted from observing the object being handled by others. While selective matching of actions cannot emerge solely as a result of the social stimulus enhancement process, object-directed behaviours may increase in frequency and variability as the result of sustained interest.

The experimenter handled all objects on all sessions, with or without modelling, for about 5 - 10 seconds, before offering them to children. In sessions where modelling was not scheduled, the experimenter turned the objects in her hands, looked at them and exclaimed to draw the children's attention. However, modelling was more vigorous and presumably more interesting than this basic handling; it may have resulted in stronger social stimulus enhancement.

Indeed, it appears that all children showed lower rates of responses, across all their objects, in Sessions 1 - 3, before modelling was presented on any of the objects, than in the subsequent sessions. Across the behaviours plotted in Figures 6.3 - 6.11, children's response rates were, over all objects and children, exactly twice as high in Sessions 4 - 15 than they were in
sessions 1 - 3. This increase in responding could not have been caused solely by increased exposure to objects, because the opposite trend was noted with toys: children responded to toys less, and not more, as the study progressed. When modelling of target actions was discontinued (in Baseline 2, Sessions 13 – 15), the response rates for Jay and Ria returned to the levels recorded before modelling was introduced (in Baseline 1, Sessions 1 – 3). Thus it appears that the experimenter's modelling of target actions produced a reversible stimulus enhancement effect across all objects for the two older children. This was not true for the youngest child, Ann: her higher response rates persisted after modelling of target actions was discontinued in Baseline 2. Further, most of Ann's responses were not performed on objects; thus the increase in her response rates could not have been due to stimulus enhancement.

Generalisation of Trained Matching

The effects of modelling on children's responses could be explained by generalisation of trained matching: as discussed in Chapter 3, the experimenter's modelling of target actions may have resembled behaviours that were extra-experimentally established as discriminative stimuli for the corresponding trained matching responses. For example, the experimenter's modelling of bimanual "object-up-move" target action may have resembled a trained high waving performed with toys held in one hand, and evoked the corresponding (approximate) responses.

The trained matching responses probably included unimanual frontal waving for Jay and Ria, tapping backhand for Jay, and also possibly
unimanual lifting of objects, bimanual holding of objects, and extending a hand holding an object to side. The two older children responded with these trained actions more (Jay) or less (Ria) reliably when presented with target objects in the modelling sessions; further, they also emitted these responses comparably more frequently with the remaining objects, in the sessions in which modelling was presented on target objects.

The youngest participant, Ann, did not show evidence of generalisation of trained matching with any of her objects and actions. Her toy-directed play indicated that this child had a smaller repertoire of behaviours as compared to the older children; it is possible that she had no history of trained matching of simple object-directed actions.

Overall, the effects of modelling on children's responses were not consistent across target object/action pairs, and were not confined to the corresponding target objects. It is possible that children found it difficult to discriminate between the target object and the remaining objects; it is also possible that clearer results could have been obtained with objects that differed in texture, material, and size (as well as in shape and colour, as in the present experiment). As noted earlier, it is also possible that reinforcement for correct matching of a subset of modelled actions would have supported more consistent generalisation of trained matching across all modelled behaviours.
Affordances of Target Objects, Baseline Frequencies of Target Response Approximations, and the Advantages of Using Gestures

The target objects presented fewer specific affordances than did the standard toys of similar size and colouring, constructed of similar materials, which were presented in the first halves of all sessions. Unsurprisingly, the responses that two older children, Jay and Ria, emitted to the toys were much more varied and specific than those that they emitted to target objects; the youngest child, Ann, showed a much smaller repertoire of toy- and object-directed behaviours.

The exact target responses were never emitted on any of the objects prior to modelling of the target actions. In this respect, target objects were superior to those used in the earlier developmental studies, where high baselines of target actions were recorded with the corresponding target objects. For example, Meltzoff (1988c) reported that children's pressing of a button and opening of a hinged piece were at ceiling levels in a group of children who were not exposed to modelling of these actions.

However, in the present study the rates of some actions that were similar to the target ones were high for some objects and children. For example, Ria emitted frontal waving or extended her hand to the side on up to 100% of her sessions with individual objects prior to modelling of a similar, "object-side-wave" target action with one of the objects. Jay emitted unimanual lifting and small bimanual moves on up to 56% of his sessions with individual objects prior to modelling of a similar, "object-up-move" target action with one of the objects. Ann extended her hand to the side on
up to 50% of her sessions with individual objects prior to modelling of a similar, "object-side-wave" target action with one of her objects.

The present data show no correct matching of target actions, but also demonstrate that modelling resulted in some changes in children's approximate responses that could be attributed to generalisation of trained matching. The use of objects, any objects, may result in high baselines of approximations to at least some of the target responses, as was the case in the present study. This makes any effects of modelling more difficult to interpret. Further, as objects are designed to contain no specific affordances, so they become less discriminable; behaviours modelled on some of the objects may generalise to the remaining ones, as was likely the case in the present study, thus again making the results harder to interpret.

As discussed in Chapters 2 and 5, such problems can be avoided if gestures (behaviours performed without objects) are used instead of actions on objects. The developmental literature contains few studies in which gestures were used, and virtually none with infants aged between one and two years. Killen and Uzgiris (1981) argued that infants are less likely to imitate gestures than actions on objects, because they are more interested in object manipulations than in gesturing during their first two years of life. However, Acredolo and Goldwyn (1996) demonstrated that infants under one year old readily learn and use gestures; indeed many early games (e.g. nursery rhymes) contain gesturing with or without naming.

It seems likely that the research on early imitation moved away from
gestures because "better" results could be obtained with actions on objects; however, this is not necessarily because infants are more interested in imitating object manipulations, but because many non-imitative processes, such as social stimulus enhancement, on-line learning from object's affordances, and generalisation of children's trained object manipulations (see Chapters 2 and 4) can contribute—separately or jointly—to children's correct responding, which is then over-interpreted as imitation. The present study showed that individual children show much lesser matching of object-directed actions than that reported by Meltzoff (e.g. 1988a, 1988b) and other developmental researchers for groups of children of comparable ages, when some of the alternative, non-imitative processes are controlled for.

Experiments 2 - 5 in the present thesis examined children's matching of gestures rather than of object-directed actions. In all of these studies, target behaviours similar to those modelled in the present study were used, among a hundred or so other gestures. The cognitive developmental literature and behaviour analytic literature contain virtually no data on gestural imitation in children aged between one and three years. Thus the remaining studies in the present thesis were designed to bridge the gap between the neonatal data of Meltzoff and colleagues (e.g. Meltzoff & Moore, 1992) and the more recent data with three to six years old children of Bekkering and colleagues (e.g. Bekkering, Wolschlager, & Gattis, 2000).
Experiment 2: Matching of Gestures in 15 - 25 Month Old Children

The aim of Experiment 2 was to examine the gestural matching repertoires of children under two years of age. There were three conditions in the experiment: Familiarisation, Training Baseline Matching Relations, and Probing for Other Matching Relations.

In the first two conditions the experimenter identified, by modelling a range of conventional gestures, four matching relations already in children’s repertoires; she then reinforced correct matching until reliable baselines were established. Trained matching baselines were maintained under intermittent reinforcement throughout subsequent probing sessions. In Condition 3 the experimenter introduced modelling of many sets of arbitrary target gestures, responses to which were never reinforced or corrected; she also continued providing intermittent reinforcement for the trained (baseline) matching relations. Target gestures included: (i) large arm movements, (ii) small hand movements performed away from body, (iii) small hand movements performed on (touching) body parts, and (iv) hand-to-body touches. A total of 77 gestures were used in this condition; each child was presented with modelling of 40 or more target gestures.
METHOD

Participants

Two girls and two boys, aged between 15 and 18 months at the start of the experiment, and 22 to 25 months at the end, participated in this experiment. All children were attending the Nursery at least three days per week, and were recruited by parental consent. The Griffiths Mental Development Scales' scores (Griffiths, 1954), obtained at the end of the experiment for three children, showed that they were developing normally (see Table 7.1).

Table 7.1. The participants' general quotient (GQ) scores, gender, and age in months and days (m-d) at the start and end of Experiment 2.

<table>
<thead>
<tr>
<th>Child</th>
<th>GQ score</th>
<th>Gender</th>
<th>Age at start (m-d)</th>
<th>Age at end (m-d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat</td>
<td>*</td>
<td>female</td>
<td>18-24</td>
<td>25-13</td>
</tr>
<tr>
<td>Gwen</td>
<td>114</td>
<td>female</td>
<td>17-15</td>
<td>24-07</td>
</tr>
<tr>
<td>Nat</td>
<td>107</td>
<td>male</td>
<td>16-18</td>
<td>23-18</td>
</tr>
<tr>
<td>Jam</td>
<td>105</td>
<td>male</td>
<td>15-10</td>
<td>22-05</td>
</tr>
</tbody>
</table>

* Cat refused to participate in the Griffiths' test. The Nursery staff and the experimenter agreed that she was a bright child, albeit unusually wary of strangers.

Two children came from monolingual (English speaking) families and two
were exposed to both English and Welsh. Griffiths comprehension scores showed that all children were competent English listeners.

**Materials and Apparatus**

Materials and apparatus were the same as in Experiment 1, except for the following:

- The secure infant chair in which participants were seated at all times had its front trey removed (to facilitate infants' forward movements).
- The experimenter sat facing a child on a beanbag, not the floor.
- There was a chest containing toys for reinforcement and play.
- Trial presentation (paper) sheets were placed on the floor below the infant seat and used by the experimenter to schedule trials throughout all sessions, as well as for preliminary coding of responses immediately after each session.

**Design**

A single-participant design, appropriate for investigating individual children's matching repertoires, was employed in the present experiment. Replication across four participants was included as a control for generalisibility and reliability of the findings. The data were presented in graphs and tables; these were analysed visually. Statistical analyses were not used. The stages of the experiment are presented in Figure 7.1.
Condition 1

**Familiarisation**

Play in Nursery common room and one-to-one play in test room.

---

Condition 2

**Training Baseline Matching Relations**

Identify 4 gestures to which a child responds with correct matching at least some of the time.

Train 4 chosen baseline matches under 100% and 50% reinforcement until reliable matching baseline is established.

---

Condition 3

**Probing for Other Matching Relations**

Present baseline (trained) and new (target) models; provide intermittent reinforcement for trained matches only.

**Target Gestures**

40-55 gestures for each child (presented in sets of 4 and 5)

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**Figure 7.1.** The stages of Experiment 2.
Procedure

**Condition 1: Familiarisation**

The experimenter played with each child for several weeks; first in the playroom setting with other children and nurses present, second in the isolated test room. This continued until the participants were happy, responsive, and comfortable with the experimenter and the new surroundings. The familiarisation play was age appropriate, with an emphasis on turn-taking and give-and-take games with toys.

Throughout the months in which the experiment was conducted, the experimenter spent many additional hours with the participants, taking part daily in the Nursery routines (including feeding, outings, and indoor play activities). The experimenter was treated by children and staff as one of the nurses, albeit more likely than most to engage in one-to-one play.

In all conditions of the experiment, a child was to be returned to the playroom if he or she cried or in other ways seemed distressed. This seldom happened (and only in the earliest trials); a few sessions were terminated prematurely when the experimenter judged the participants to be feeling unwell. Children were tested daily, when they were available, alert, and happy to play, with unavoidable breaks for holidays and illnesses. A typical experimental session lasted just over 15 minutes. Occasionally, when a participant was exceptionally happy and responsive, more than
one session was run in a single day.

**Condition 2: Training Baseline Matching Relations**

In the first part of this condition, the experimenter started modelling conventional gestures as part of play. The earlier pilot work revealed that varying the models until gestures that evoked well-established matching responses were found for each individual child was less time consuming than attempting to train poorly or unreliably matched gestures within the experiment. Thus the experimenter continuously adjusted the sets of four conventional gestures presented to each child until the gestures that evoked the child's correct matching responses at least some of the time were identified. Operant training was conducted in the second part of this condition to establish reliable and consistent correct responding to the verbal request, "Do this," followed by modelling of these gestures.

Each training session contained three trials of each of the four chosen gestures (12 trials per session), with up to three models per trial. The gestures were modelled in a predetermined randomised order, with an added constraint that no more than two trials of the same gesture were presented in succession. The sessions usually started with warm-up play; the experimenter then removed the toys and asked, "Shall we play our game?" Modelling trials commenced next. The experimenter made sure that the participant was attentive by touching his or her feet, calling his or her name, or saying, "Look at me!" She then asked, "Can you (name) do this?" before modelling a baseline gesture.
Models were always clear and exaggerated; for example in the “hands up” gesture the experimenter stretched her arms upwards as far as possible, looking up at her hands, and when modelling “peek-a-boo” she opened her hands to reveal her wide open eyes, while saying “boo”. After modelling a gesture the experimenter looked at the child expectantly; if the child did not respond immediately she prompted him or her to do so by saying, "You do it!" or "Show me!" If the child did not respond to prompting, the experimenter modelled the same gesture again, up to three times per trial type. If no response was emitted the experimenter used putting through to gently move a participant’s hands so as to produce the required matching response and promptly presented reinforcement. Non-matching (incorrect) responses were corrected in a similar manner, with a verbal instruction, "Not quite; this is how we do it!" and putting through followed by reinforcement. The correct matching responses were enthusiastically reinforced by clapping, exclaiming, "Yeah!" or "Well done!" and play with toys and stickers.

All sessions ended with play. The training proceeded with a 100% reinforcement rate until the predetermined criterion of at least five out of six correct responses to each of the four baseline models, over two consecutive sessions, was reached. The reinforcement rate was then reduced to 50%, and when a child responded correctly on at least 11 out of 12 trials within a single session—across gestures—the training was considered complete. A list of gestures used in this condition is presented in Table 7.2.
Table 7.2. Trained baseline matching relations: descriptions of modelled gestures and corresponding correct matching responses. (Note: All of these gestures are illustrated in Figures 7.2 – 7.5 which present individual children’s response data.)

<table>
<thead>
<tr>
<th>Gesture</th>
<th>Model Description</th>
<th>Correct Responses</th>
<th>Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>HANDS ON HEAD</td>
<td>Both hands placed on top of head, hands still or tapping (presented with body swaying for Participant Cat).</td>
<td>Both hands on head, touching hair.</td>
<td>Cat, Nat</td>
</tr>
<tr>
<td>PEEK-A-BOO</td>
<td>Both hands covering eyes, then hands opening wide while the experimenter says 'boo'.</td>
<td>Both hands on face.</td>
<td>Jam</td>
</tr>
<tr>
<td>HANDS UP</td>
<td>Both hands over head, stretching, looking up.</td>
<td>Both hands at head level or above.</td>
<td>Gwen, Jam, Nat</td>
</tr>
<tr>
<td>PALM POINT</td>
<td>Index finger of right hand touching or tapping up-turned palm of left hand.</td>
<td>Index finger of right hand touching left palm.</td>
<td>Gwen</td>
</tr>
<tr>
<td>HANDS ON BELLY</td>
<td>Both hands tapping middle of body (belly/chest).</td>
<td>Both hands touching middle of body.</td>
<td>Cat, Jam, Nat</td>
</tr>
<tr>
<td>HAND TO MOUTH</td>
<td>Palm of right hand tapping open mouth to produce sound 'ahh'.</td>
<td>Right hand touching mouth.</td>
<td>Nat, Gwen, Cat</td>
</tr>
<tr>
<td>TONGUE OUT</td>
<td>Tongue extended out in front.</td>
<td>Tongue shown.</td>
<td>Cat</td>
</tr>
<tr>
<td>DANCING</td>
<td>Upper body producing a dancing movement with hands on side and shoulders circling.</td>
<td>Distinct dancing movement of upper body and shoulders.</td>
<td>Gwen</td>
</tr>
<tr>
<td>SWAYING</td>
<td>Upper body and shoulders producing a swaying movement (side-to-side) with hands on side.</td>
<td>Distinct swaying side-to-side movement of upper body and shoulders.</td>
<td>Jam</td>
</tr>
</tbody>
</table>
Condition 3: Probing for Other Matching Relations

Many arbitrary target gestures, including whole body movements, large arm movements, small hand movements, and hand-to-body touches, were presented in this condition. Initially, for each child, four target models were interspersed with the four baseline trained models, and there were two trials per gesture per session (16 trials in all). In the later sessions the experimenter increased the sets of target models to five; with four baseline models and two trials per gesture there were now 18 trials per session in all.

As in the previous condition, the experimenter asked, "Shall we play our game?" She then attracted the child's attention and asked, "Can you (name) do this?" before modelling a gesture. Correct responses to trained baseline models were reinforced intermittently; there were no scheduled consequences (reinforcement or correction) for responses to target models. The experimenter smiled at all times while modelling and observing the children's responses, in both trained and target gesture trials. Smiling was presented unconditionally in order to ensure that responding in target gesture trials was not suppressed as might have been the case if such trials were selectively followed by a "still face" expression by the experimenter.

The number of trials in which each target gesture was modelled differed between individual gestures and children: as a general rule, modelling of each target gesture continued until a child's responding appeared to have stabilised (however, no strict criterion for stability was applied). For example, a "palms-up bowl" gesture was modelled to Jam over 11 trials;
initially, his responses were variable and contained turning palms up with his hands separated and touching his eye(s); Jam then emitted one good target response approximation and two correct responses in his last three trials, at which point modelling of this target gesture was discontinued. The illustrated lists of all target gestures and descriptions of the children's responses are presented in Tables 7.6 - 7.11 (see Results).

At the end of the experiment a trained member of the Nursery and University staff tested the children on the Griffiths Mental Development Scales (Griffiths, 1954). This was done in the familiar test room, and the experimenter was present as a familiar adult to encourage the participants to complete all the tasks. Some of the scores on the social development scale were assigned by questioning those Nursery staff who were most familiar with the individual children.

Finally, videotapes containing representative recordings of testing were presented to parents, who were encouraged to ask questions and comment on what they had seen. Parents also received letters with a comprehensive explanation of the procedures and the results of the study, and the Griffiths' reports. The children received small toys.
Coding

**Condition 2 Baseline and Condition 3 Probing Trials**

The experimenter modelled each gesture up to three times on each trial, until the child emitted a response. The following were not counted as responses in baseline and probing trials:

- Turning away.
- Pointing at toys.
- Vocalising.
- Trying to stand up.
- Kicking the footrest
- Holding onto the chair.
- Touching or pulling clothes.
- Touching the safety belt/buckle.
- Touching the wooden screen.
- Extending arms to experimenter (to be picked up).
- Yawning.

In Condition 2 baseline sessions, while matches were being trained, clapping did not count as a response. The experimenter clapped as part of reinforcement, and most children started clapping after, between, and sometimes before responding; this was usually transient. In Condition 3
probing sessions clapping was coded as a response whenever it was emitted to either trained models or target gestures.

Occasionally, more than one response was emitted to modelled gestures. Whenever this happened, all responses were noted; however, only the last responses were presented in the analyses, unless stated otherwise (i.e. when changes in responding within trials were themselves analysed). Thus an incorrect response promptly followed by a correct response was counted as correct; for example, touching the head with one hand but then repeating the gesture with both hands was coded as a correct “hands on head” when emitted to the appropriate model; it received reinforcement when scheduled. Conversely, a correct response promptly followed by an incorrect response was counted as incorrect; for example, a child tapping the middle of his or her body in response to the corresponding model, but then placing hands on eyes, was coded as incorrect.

Intra- and Inter- Observer Reliability

Coding of responses was performed by the experimenter immediately after each session, and again at the end of the experiment; this was done by examining the video recordings. Slow- and stop-motion facilities were used; each response was viewed as many times as necessary.

Children's responses to baseline and target models were classified into four main categories:

1. Correct: Tables 7.2 and 7.6 – 7.11 show exact criteria for each gesture.
2. *Mirror*: same configuration as correct, but performed with left hand to right hand models and with right hand to left hand models.

3. *Incorrect*: all responses that were not coded as correct or mirror were included in this category; exact descriptions were recorded.

4. *No response*.

The following were also noted:

- The number of models (1-3) needed to evoke a response.
- The form of each incorrect gesture.
- Whether reinforcement was given (baseline responses only).

Across children, responses were recorded over a total of 3097 trials; these included 1892 trained (baseline) trials in Conditions 2 and 3, and 1205 target trials in Condition 3. The experimenter coded all responses immediately after testing; the responses for 908 target trials were coded again later, without reference to the first codes. Thus intra-observer agreement was calculated across 75% of target trials (this represented 30% of all data). The agreement was excellent: children's responses were coded the same with respect to four main coding categories of correct, mirror, incorrect, and no response, on 98% of all double-coded trials.

Finally, 25% of all target trials were coded independently by a postgraduate researcher with experience in working with children under two years old. Inter-observer agreement was excellent: 96% of the target responses were coded the same across the four categories of correct, incorrect, mirror, and no responses. The few disagreements were clarified.
through viewing of tapes and discussion.

RESULTS

Table 7.3 shows, for each participant, the number of sessions in Condition 2 baseline training and Condition 3 probing, the total number of target gestures, and the total number of target trials.

<table>
<thead>
<tr>
<th>Child</th>
<th>Condition 2 (baseline) sessions</th>
<th>Condition 3 (probing) sessions</th>
<th>Target gestures (total)</th>
<th>Target trials (total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat</td>
<td>26</td>
<td>30</td>
<td>43</td>
<td>248</td>
</tr>
<tr>
<td>Gwen</td>
<td>12</td>
<td>26</td>
<td>41</td>
<td>231</td>
</tr>
<tr>
<td>Nat</td>
<td>15</td>
<td>43</td>
<td>55</td>
<td>388</td>
</tr>
<tr>
<td>Jam</td>
<td>16</td>
<td>35</td>
<td>40</td>
<td>338</td>
</tr>
</tbody>
</table>

**Conditions 1 and 2: Familiarisation and Training Baseline**

**Matching Relations**

Familiarisation with the participants in the common rooms, where the experimenter participated in daily Nursery routines (see Procedure),
took several weeks. Next, the children were taken to the testing room; at this point only a couple of short sessions were needed with each child to establish turn-taking and one-to-one play interaction with the experimenter. Children showed some curiosity about the new environment—they looked around and pointed—but this receded within a single session: the room was bare, contained only necessary furniture, and was designed to be uninteresting.

The number of sessions required to establish consistent correct matching of four baseline gestures (see Table 7.3) varied between individual participants: Condition 2 training of baseline matching relations took between 12 and 26 sessions to complete. As noted in the Procedure, the experimenter modelled a range of conventional gestures, waiting for some correct matching to appear, and then attempted to train these baseline matching relations until they were emitted reliably, rather than to shape entirely new matches. Thus the experimenter relied on generalisation of matching that may have been established outside of the experiment. All children started responding to at least some of the baseline models within the first two sessions.

Children's correct matching responses to trained (baseline) models in Condition 2 sessions are presented in Figures 7.2 - 7.5.
Figure 7.2. Four trained (baseline) matching relations for Participant Gwen. The filled squares show numbers of correct matching responses (out of a maximum of three); these are plotted for each of four trained gestures, across 12 baseline sessions. The unfilled squares show correct responses to other gestures that the experimenter attempted to evoke/train, but to which good matching was not established; these gestures were then replaced with the pictured ones. The reinforcement rate was 50% where shaded grey, and 100% on all other sessions. Baseline training started when Gwen was 17 months old, and ended when she was 20 months old; the break in the graph represents a 10 week long break in the training.
Figure 7.3. Four trained (baseline) matching relations for Participant Jam. The filled squares show numbers of correct matching responses (out of a maximum of three); these are plotted for each of four trained gestures, across 16 baseline sessions. The unfilled squares show correct responses to other gestures that the experimenter attempted to evoke/train, but to which good matching was not established; these gestures were then replaced with the pictured ones. The reinforcement rate was 50% where shaded grey, and 100% on all other sessions. Baseline training started when Jam was 15 months old, and ended when he was 18 months old; the break in the graph represents re-training of the baseline set after a 10 week long break in the experiment.
Figure 7.4. Four trained (baseline) matching relations for Participant Nat. The filled squares show numbers of correct matching responses (out of a maximum of three); these are plotted for each of four trained gestures, across 15 baseline sessions. The unfilled squares show correct responses to other gestures that the experimenter attempted to evoke/train, but to which good matching was not established; these gestures were then replaced with the pictured ones. The reinforcement rate was 50% where shaded grey, and 100% on all other sessions. Baseline training started when Nat was 17 months old, and ended when he was 20 months old; the break in the graph represents re-training of the baseline set after a 10 week long break in the experiment.
Figure 7.5. Four trained (baseline) matching relations for Participant Cat. The filled squares show numbers of correct matching responses (out of a maximum of three); these are plotted for each of four trained gestures, across 26 baseline sessions. The unfilled squares show correct responses to other gestures that the experimenter attempted to evoke/train, but to which good matching was not established; these gestures were then replaced with the pictured ones. The reinforcement rate was 50% where shaded grey, and 100% on all other sessions. Baseline training started when Cat was 18 months old, and ended when she was 21 months old; the break in the graph represents a 10 week long break in the training.
Figure 7.2 shows that reliable matching of four conventional gestures was established over 12 sessions for Gwen; her correct matching developed steadily and only two gestures were tried and abandoned. Gwen's performance was disrupted after a 10 week long break in the training but recovered within four sessions.¹

Figure 7.3 shows that training of baseline matching relations was completed in 12 sessions for Jam; three gestures were matched well from the start and three other gestures were tried and abandoned. A further four sessions were run to ensure that Jam's baseline responding remained good after a 10 week break in the experiment; his performance was not disrupted by this break.

Figure 7.4 shows that reliable matching of 4 conventional gestures was established over 10 sessions for Nat; a total of 5 additional gestures were tried and abandoned. A further 5 sessions were run to ensure that Nat's

¹ There was a 10 week break in the experiment for all children, due to experimenter's leave from the Nursery. At this point, two children (Cat and Gwen) were in Condition 2 (training of baseline matching relations) and the remaining two children were in Condition 3 (probing for other matching relations). For the later children (Nat and Jam) the experimenter re-presented several baseline training sessions before proceeding with the probing sessions. As can be seen from Figures 7.3 and 7.4, this was done as a precaution only—participants' matching of trained baseline relations was not disrupted by this long break.
baseline responding remained good after a 10 week break in the experiment; his performance was not disrupted by this break.

Figure 7.5 shows that reliable matching of four conventional gestures was comparably more difficult to establish with Cat. Her baseline training took 26 sessions to complete; correct matching developed slowly and performance remained variable over many trials; 7 additional gestures were tried and abandoned. Cat's performance stabilised in the last Condition 2 sessions, but her responses remained comparably small: for example, she usually responded to "hand to mouth" models by touching her mouth (silently) once, whereas Nat responded to the same models by enthusiastically tapping his mouth while producing loud "ahhh" sounds.

**Condition 3: Probing for Other Matching Relations**

**Trained (Baseline) Gestures**

In this condition the trained (baseline) gestures continued to be modelled. Correct trained matching responses were reinforced at about 50% on average; the rates varied between children and sessions. The experimenter occasionally produced extra reinforcers if children's responding seemed hesitant; this happened in some early probing sessions. Conversely, the rates were often reduced to about 25% in the later sessions, when "playing the matching game" in the experimental room became a well-established routine. Play happened at the end of each session, and there were play-breaks in between trials whenever children seemed less than enthusiastic.
Probing sessions were run over several months for all children. Overall, they found these one-to-one interactions reinforcing: most of the time the participating children approached the experimenter as soon as she appeared in the common room and asked to be taken out to the experimental room.

All children responded promptly and reliably to trained (baseline) models across all Condition 3 probing sessions. Although up to three models could be presented on each trial, this was seldom necessary; overall children had very few errors and even fewer trials where no responses were emitted. Table 7.4 shows, for each child, total numbers of trained (baseline) trials, percentages of these trials in which more than one model was needed to evoke a response, and percentages of target trials in which no responses were recorded. Figure 7.6 shows children's response data.

Table 7.4. Total numbers of trained (baseline) trials in Condition 3 probing, percentages of these trials in which more than one model was needed to evoke a response, and percentages of target trials in which no responses were recorded, for all participants.

<table>
<thead>
<tr>
<th>Child</th>
<th>Trained trials</th>
<th>Trials with more than 1 model (%)</th>
<th>Trials with no response (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat</td>
<td>240</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Gwen</td>
<td>208</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Nat</td>
<td>344</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Jam</td>
<td>280</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>
Figure 7.6. Matching of baseline gestures in Condition 3 probing sessions for all participants.

The correct matching responses (out of a maximum of eight) are plotted jointly for the sets of four baseline (trained) gestures, for each participant, across sessions. The breaks in the graphs for Participants Nat and Jam represent a 10 week long break in the experiment (at these points matching was re-trained). The dashed lines in all graphs indicate the points at which five rather than four target gestures were presented in each session (see Procedure).
Figure 7.6 shows that correct responses to trained (baseline) models were recorded on 91% of trials for Gwen and Nat, on 92% of trials for Cat, and on 94% of trials for Jam.

\section*{Target Gestures}

Target gestures were presented, randomly interspersed with modelling of trained (baseline) gestures, with two trials per gesture per session. In the earlier sessions, the target sets contained 4 gestures (with 8 trials per session), and in the later sessions they contained 5 gestures (with 10 trials per session); more target trials were presented in the later sessions because "the matching game" was so well established by this point that children continued responding to all models even with as few as two reinforcers (for trained responses) per session containing 18 trials.

All children responded promptly and reliably to target models across all Condition 3 probing sessions, although their responses to these models were never reinforced (save for unconditional smiling that was presented in all trials, see Procedure). As was the case for trained (baseline) gestures, up to three models could be presented on each trial; however, this was not necessary on the majority of trials. Further, children seldom failed to respond to modelling of target gestures. Table 7.5 shows, for each child, the total numbers of target trials, the percentages of these trials in which more than one model was needed to evoke a response, and the percentages of the target trials in which no responses were recorded.
Table 7.5. Total numbers of target trials in Condition 3 probing, percentages of these trials in which more than one model was needed to evoke a response, and percentages of target trials in which no responses were recorded, for all participants.

<table>
<thead>
<tr>
<th>Child</th>
<th>Target trials</th>
<th>Trials with more than 1 model (%)</th>
<th>Trials with no response (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat</td>
<td>248</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>Gwen</td>
<td>231</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Nat</td>
<td>388</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>Jam</td>
<td>338</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

All Target Gestures: Children's Hand Preferences

Figure 7.7 shows the handedness of children's responses to target gestures that were modelled with (i) the right-hand, (ii) the left hand, and (iii) the both hands, across all target gestures. The figure shows that three children (Cat, Gwen, and Jam) showed marked preferences for right hand responding, while the remaining child (Nat) responded with his right hand and with his left hand on about equal proportions of trials (though he showed a slight trend towards the left hand preference). The hand preference was most marked for Jam, who emitted right handed responses 10 to 20 times more often than left handed responses when presented with unimanual target models; he also responded with his right hand on a substantial proportion of trials where bimanual gestures were modelled.
Figure 7.7. Percentages of target trials in which participants emitted right handed responses (red bars), left handed responses (blue bars), and bimanual responses (yellow bars). Target gestures were modelled either with (i) the right-hand, or (ii) the left hand, or (iii) both hands.

As can be seen from Figure 7.7, two participants, Gwen and Nat, showed some evidence of mirroring (responding in the same space as the experimenter). They emitted (i) comparably more left handed responses to the right hand models than to the left hand ones, and (ii) comparably more right handed responses to the left hand models than to the right hand
ones. The remaining two participants, Cat and Jam, showed no evidence of mirroring: their responding was unaffected by the hand used for modelling.

Nat's data show that he frequently emitted bimanual responses to unimanual models (bimanual-for-unimanual errors); however, he emitted unimanual responses to bimanual models (unimanual-for-bimanual errors) on a much smaller proportion of trials. Gwen's data show a similar trend, although she committed comparably fewer errors of this type overall; she had some bimanual-for-unimanual errors, but no unimanual-for-bimanual errors. Jam showed the opposite trend: his unimanual-for-bimanual errors (all such responses were performed with the preferred right hand) were more frequent than bimanual-for-unimanual errors. The remaining child, Cat, committed bimanual-for-unimanual errors and unimanual-for-bimanual errors on equal proportions of trials.

**All Target Gestures: Consistency of Children's Responding Within and Across Trials**

The consistency of children's matching was examined within trials that contained more than one response, and also across trials for those target gestures to which four or more responses were recorded.

Children's performances on trials with more than one response were classified as follows:

1. Improving. This was whenever the last response was correct or a mirror
while the first response was incorrect; it was also whenever the last response was a better approximation to the modelled target gesture than the first one (e.g. when a child, presented with a bimanual "thumbs up" gesture, first responded by extending right hand and then by extending both hands).

2. Getting worse. This was whenever the last response was incorrect while the first response was correct or a mirror; it was also whenever the last response was a lesser approximation to the modelled target gesture than the first one (e.g. when a child, presented with a "hand to shoulder" touch, first touched the shoulder and then touched the chest or arm).

3. Being consistent. This was whenever both the first and the last responses were either correct/mirror or incorrect; it was also whenever the responses were equally good approximations to the modelled target gesture (e.g. when a child, presented with a "nose wiggle" model, in which a hand touched nose and showed a wiggling movement at the same time, first responded by touching nose without the wiggle and then performed the wiggle without touching nose).

Figure 7.8 shows, for individual children, the total numbers of trials where more than one response was emitted, and the percentages of these trials in which responding was coded as improving, getting worse, or being consistent. The figure shows that children responded more than once in between 15 and 29% of all their target trials; within these multiple-response trials, all children improved more often than they got worse.
**Figure 7.8.** The percentages of multiple-response trials in which responding was coded as improving (red bars), getting worse (blue bars), and remaining consistent (yellow bars), are plotted along the Y axis, for all children, and across all target gestures. Total numbers of trials where more than one response were emitted, and percentages of all target trials that these represented, are given for each child along the X axis.

The consistency of children's performances across trials (over time) was examined for the individual target gestures to which more than four responses were recorded: responses emitted in the first half of modelling trials were compared to those from the last half of modelling trials, for each of these gestures. Children's matching was classified as follows:

1. **Improving.** This was whenever more correct and mirror responses were emitted in the last trials than in the first trials; it was also whenever the last trials contained better approximations to the modelled target gesture than the first trials.
2. Getting worse. This was whenever fewer correct and mirror responses were emitted in the last trials than in the first trials; it was also whenever the last trials contained lesser approximations to the modelled target gesture than the first trials.

3. Being consistent. This was whenever there were equal numbers of correct and mirror responses in the last and the first trials; it was also whenever the number of approximations to the modelled target gestures were equal in the first and the last trials.

Figure 7.9 shows, for individual children, the total numbers of target gestures for which more than four responses were recorded, and the percentages of the latter gestures for which responding across multiple trials was coded as improving, getting worse, or being consistent. This figure shows that, for all children, responding remained consistent across trials (over time) for comparably more target gestures than for which it improved or got worse. For three children (Cat, Nat, and Jam) responding got worse and improved over trials on the similar proportions of target gestures (or perhaps got worse slightly more often than improved). Thus, overall, these children's matching of target models remained consistent over time.

Gwen was the only child whose performance over trials improved on over six times more gestures than it got worse. Getting worse was recorded for only two of her gestures, and here the differences were small, each involving one fewer approximations to the target model in the later sessions than in the earlier ones. This was true of most changes in performances for better or worse across the remaining three children: the
differences in responding between the early and late trials were very small across most gestures. However, Gwen’s improvements were not only more numerous than those of the remaining children; they were also more substantial across several target gestures. Gwen’s correct responding developed gradually from partial approximations and, once achieved, was reliably evoked by modelling in all the later trials. The descriptions of Gwen’s responses are presented for individual gestures in Tables 7.7 - 7.11; her most marked improvements were recorded for the “hand circle”, “tiger”, “bird facing”, “nose points” and “horns” gestures.

**Figure 7.9.** The percentages of gestures in which responding was coded as improving (red bars), getting worse (blue bars), and remaining consistent (yellow bars), across sessions (over time) are plotted along y axis, for all children. Total numbers of gestures where more than four responses were recorded (that were used for these analyses) are given for each child along x axis.
In the following paragraphs and tables children's responses to target gestures are described in detail for each individual gesture. The gestures were grouped into the following categories:

1. Target gestures that were trained (baseline) for some of the children, and then presented as targets to some of the remaining children, together with the gestures that contained similar physical components.

2. Target gestures that contained large arm movements.

3. Target gestures that incorporated small hand movements, performed away from body.

4. Target gestures that contained small hand movements, performed on body parts.

5. Hand touches to upper and lower body locations.

6. Hand touches to arm locations.

**Baseline Gestures Presented as Targets and Other Similar Gestures**

*(11 Gestures)*

Seven gestures that were used as trained (baseline) gestures for some of the children were also presented as target gestures for some of the remaining children; four other physically similar gestures were also presented. Tables 7.6.a and 7.6.b show illustrated lists of these 11 gestures with the descriptions of models and of responses that were emitted to them. The tables show that, overall, children's responses to these gestures were correct and, for most gestures and children, reliably evoked by modelling.
Table 7.6.a. Descriptions of models and responses for gestures that were used as baseline (trained) for some children and then presented as target gestures to other children. The bracketed numbers (last column) represent numbers of trials over which a gesture was presented as a target.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Baseline for...</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tongue extended out in front.</td>
<td>Cat</td>
<td>Gwen (2)</td>
<td></td>
</tr>
<tr>
<td>RESPONSES: Correct on both trials (tongue clearly shown).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tongue out</td>
<td>Cat, Nat</td>
<td>Gwen (2)</td>
<td></td>
</tr>
<tr>
<td>RESPONSES: Correct on both trials (hands tapping head).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both hands on top of head, once or tapping.</td>
<td>Jam</td>
<td>Cat (2)</td>
<td></td>
</tr>
<tr>
<td>RESPONSES: Correct on both trials (hands over eyes, open wide).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both hands covering eyes, open wide with a Jam Cat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RESPONSES: Correct on both trials (hands raised over head).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both hands over head, stretching, and looking up.</td>
<td>Gwen, Jam, Nat</td>
<td>Cat (2)</td>
<td></td>
</tr>
<tr>
<td>Swaying</td>
<td>Jam</td>
<td>Nat (5)</td>
<td></td>
</tr>
<tr>
<td>RESPONSES: No response on first 4 trials, then a correct response.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index of right hand touching or tapping Gwen Jam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RESPONSES: Correct responses on 5/6 trials (right index on left palm).</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7.6.b. Descriptions of models and responses for gestures that were used as baseline (trained) for some children and then presented as target gestures to other children; also for several physically similar target gestures that were not used as baseline gestures. The bracketed numbers (last column) represent numbers of trials over which a gesture was presented as a target.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Baseline for...</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swaying &amp; hug</td>
<td>Upper body/shoulders producing a swaying side-to-side movement; arms hugging body.</td>
<td>NOT USED AS BASELINE.</td>
<td>Nat (3)</td>
</tr>
<tr>
<td></td>
<td>RESPONSES: More reliably evoked than swaying without hugging; side-to-side body movement was emitted on all trials but hugging (modelled large) was matched by a small hand touch/overlap in front of body.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rocking</td>
<td>Upper body/shoulders producing a rocking front-and-back movement; arms resting in front of body.</td>
<td>NOT USED AS BASELINE.</td>
<td>Nat (2)</td>
</tr>
<tr>
<td></td>
<td>RESPONSES: No response once; correct and expansive movement once.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hands to middle</td>
<td>Both hands tapping middle of body (belly/chest).</td>
<td>Jam, Cat, Nat</td>
<td>Gwen (2)</td>
</tr>
<tr>
<td></td>
<td>RESPONSES: Correct on both trials (hands tapped chest).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right hand on middle</td>
<td>Right hand tapping middle of body (belly/chest).</td>
<td>NOT USED AS BASELINE.</td>
<td>Gwen (2)</td>
</tr>
<tr>
<td></td>
<td>RESPONSES: Correct on both trials (right hand tapped chest).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left hand on middle</td>
<td>Left hand tapping middle of body (belly/chest).</td>
<td>NOT USED AS BASELINE.</td>
<td>Gwen (4)</td>
</tr>
<tr>
<td></td>
<td>RESPONSES: Mirror responses on all trials (right hand tapped chest).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


**Large Arm Movements (15 Gestures)**

Tables 7.7.a, 7.7.b, 7.7.c, and 7.7.d show illustrated lists of 15 target gestures which incorporated large arm movements, the descriptions of models, and the children's responses. These tables show that

- The bimanual "allgone" gesture, presented to four children, was a well established matching relation for all children.

- The unimanual "waving" gestures, modelled with both the right and the left hand for two children, were well established matching relations for these children, and were reliably evoked with the left and right hand models.

- The bimanual "flying" gesture, presented to three children, was probably not an established matching relation; the children responded to this model by producing two component gestures ("allgone" and "waving", described above), albeit imperfectly.

- The unimanual "arm across forehead" gesture, presented to three children, was not an established matching relation for any child; all children responded with incorrect similar gestures (e.g. placing a fist on face).

- The bimanual "up-down joined" gesture, presented to four children, was probably not an established matching relation for all children; their
responses consisted of the two component gestures ("hands joined" and "waving"), either consistently (Cat and Gwen), or on at least some occasions (Nat and Jam).

- The unimanual "hand circle" gestures, modelled with the right hand to three children and with the left hand to two children, did not appear to be established matching relations for all children; they seemed to have responded correctly by reaching forth and tracking with their own hands the experimenter's slow movement, either consistently (Gwen and Cat), or occasionally (Nat and Jam).

- The bimanual "side arms circle" gesture, presented to one child, was not a matching relation for him; he did not integrate the circular movement, that he matched—albeit jaggedly, in front, and with one hand—when presented with "hand circle" models, and arms spreading, that he matched correctly, when presented with "allgone" models (his responses were as for the bimanual "flying" gesture).

- The bimanual "pushing away" gesture, presented to one child, was not an established matching relation for him; he matched the hand extension with palms facing away but not the slow pushing movement.

- The bimanual "hands treading" gesture, presented to one child, was either an established matching relation for her, or she could have responded correctly by reaching forth and tracking with her own hands the experimenter's slow movement.
• The bimanual "rubbing hands" gesture, presented to three children, was an established matching relation for all of these children.

• The bimanual "palms-up bowl" gesture, presented to three children, appeared to be a well established matching relation for only one of them; the remaining children initially emitted several different incorrect responses that resembled the target model.

• The bimanual "palms facing" gesture, presented to one child, was not an established matching relation for him (he responded with incorrect but similar gestures, e.g. "palm point").

• The bimanual "crossed arms" gesture, presented to four children, was not an established matching relation for any child; all children responded with incorrect similar gestures (e.g. hand touches and small, hug-like overlaps on belly).
Table 7.7.a. Descriptions of models and responses for large arm movements and configurations that were presented as target gestures. The bracketed numbers represent numbers of trials.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bimanual allgone</td>
<td>Arms spread as wide as possible to sides of body.</td>
<td>Cat (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gwen (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jam (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nat (2)</td>
</tr>
<tr>
<td></td>
<td>RESPONSES: All children responded to this target gesture immediately, reliably, and correctly (with expansive, large movements).</td>
<td></td>
</tr>
<tr>
<td>Right hand waving</td>
<td>Right hand waving (repetitive up/down movement) in front of body, palm facing the child.</td>
<td>Nat (4)</td>
</tr>
<tr>
<td></td>
<td>Left hand waving (repetitive up/down movement) in front of body, palm facing the child.</td>
<td>Nat (4)</td>
</tr>
<tr>
<td></td>
<td>RESPONSES: Both children responded consistently with correct up/down movement of one hand.</td>
<td>Gwen (4)</td>
</tr>
<tr>
<td>Left hand waving</td>
<td>Arms spread as wide as possible to sides of body (as for “allgone”) together with much flapping (large repetitive up/down movement, as for “waving”).</td>
<td>Nat (14)</td>
</tr>
<tr>
<td></td>
<td>RESPONSES: All children positioned their arms in front and slightly to side, and moved them up/down; thus they produced both components of the target gesture but less expansively than it was modelled.</td>
<td>Jam (10)</td>
</tr>
<tr>
<td></td>
<td>Gwen and Jam emitted these responses reliably from their early trials; Nat’s responding developed from stationary bimanual responses (“hands on head”), to bimanual waving on sides of body.</td>
<td>Gwen (4)</td>
</tr>
<tr>
<td>Bimanual flying</td>
<td>Fisted right arm was positioned in front and head was lowered until forehead rested on the lower arm, with face down.</td>
<td>Nat (14)</td>
</tr>
<tr>
<td></td>
<td>RESPONSES: No child produced a correct response to this target gesture.</td>
<td>Jam (10)</td>
</tr>
<tr>
<td></td>
<td>Jam responded by placing his fist(s) on his temple, forehead, and eye(s); Cat placed her right fist on her eye, cheek, and mouth; Nat’s responses included bimanual touches to head, eyes, and mouth; he crossed his wrists on the last two trials: this was a good approximation to the &quot;crossed arms&quot; gesture, to which such good responses were never emitted.</td>
<td>Cat (4)</td>
</tr>
</tbody>
</table>
Table 7.7.b. Descriptions of models and responses for large arm movements and configurations that were presented as target gestures. The bracketed numbers represent numbers of trials.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arms extended in front, with hands joined, performed an expansive and repetitive up/down movement.</td>
<td>Nat (18) Jam (8) Gwen (2) Cat (2)</td>
<td></td>
</tr>
<tr>
<td>RESPONSES: All children emitted at least one correct response each, with hands joined in front and some up-down movement.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cat and Gwen’s responses were all correct, slow, and showed large movements; Gwen performed these straight away, and Cat (on both her trials) started waving with her hands separated and then repeated the movement with her hands joined.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jam and Nat did not always respond to this model; their responses were mainly bimanual up-down waves in front with their hands separated; they also occasionally joined hands without performing the movement. Nat’s responding got better over trials; correct responses were emitted in the last two trials. After producing a single correct response Jam continued, over several trials, to respond incorrectly.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right hand performed a repetitive circular movement in front of body; palm facing the child.</td>
<td>Nat (8) Jam (8) Gwen (4)</td>
<td></td>
</tr>
<tr>
<td>Left hand performed a repetitive circular movement in front of body; palm facing the child.</td>
<td>Nat (6) Cat (2)</td>
<td></td>
</tr>
<tr>
<td>RESPONSES: All children performed at least one correct unimanual circular movement each.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jam did not respond consistently to this model; he responded incorrectly by lifting hand(s) up and/or performed small waving (up-down) movements; his only correct response was followed by an incorrect one. Nat’s responding got somewhat better over trials: he mainly responded with unimanual movements, most of which were waves (up-down); in the later trials some small and jagged circular movements appeared and alternated with waving.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gwen responded correctly on all her trials; her responding got smoother over trials as very clear circular movements developed and persisted after the experimenter finished modelling the gesture. Cat also responded correctly on both her trials, following the experimenter’s movement.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7.7.c. Descriptions of models and responses for large arm movements and configurations that were presented as target gestures. The bracketed numbers represent numbers of trials.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bimanual side arm circle</td>
<td>Arms spread as wide as possible to sides of body (as for &quot;allgone&quot;), together with synchronised circular movement. RESPONSES: Nat responded with waving (up-down) movement performed bimanually on sides of body. This response resembled the &quot;flying&quot; gesture: Nat's responses were actually better approximations to flying (more expansive and with a larger movement) when emitted to this model than to the appropriate one.</td>
<td>Nat (2)</td>
</tr>
<tr>
<td>Bimanual pushing away</td>
<td>Both arms in front of body, performed a slow and deliberate pushing movement away from body, stretching as far as possible, with palms facing the child. RESPONSES: Nat’s responding got better over trials: in the early trials he emitted some incorrect trained bimanual responses (e.g. tapping middle, clapping) but then started extending his hands in front, with palms facing the experimenter. The pushing movement was either absent or brief; however, Nat seemed to retrieve his extended hands slowly on several trials, thus perhaps following the experimenter's movement as seen from his perspective.</td>
<td>Nat (10)</td>
</tr>
<tr>
<td>Bimanual treading</td>
<td>Both arms in front of body, with palms facing the child; the right and left hand performed alternate slow pushing and retreating movements. RESPONSES: Cat responded correctly to this model on both her trials.</td>
<td>Cat (2)</td>
</tr>
<tr>
<td>Bimanual rubbing hands</td>
<td>Both hands extended in front of body, joined, with palms rubbing vigorously. RESPONSES: All children responded correctly to modelling of this target gesture. Nat emitted correct responses on both his trials and so did Cat; Jam's responding was mostly correct, but not reliably so: he had trials on which hands were together but rubbing was not performed, where fingers were knotted together, and where clapping was emitted.</td>
<td>Jam (14) Nat (2) Cat (2)</td>
</tr>
</tbody>
</table>
Table 7.7.d. Descriptions of models and responses for large arm movements and configurations that were presented as target gestures. The bracketed numbers represent numbers of trials.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bimanual palms-up bowl</td>
<td>Both hands extended in front of body, joined, with palms facing up and slightly cupped.</td>
<td>Jam (11) Cat (10) Nat (2)</td>
</tr>
<tr>
<td><strong>RESPONSES:</strong> All children emitted at least one correct response each.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nat responded correctly on both his trials.</td>
<td></td>
</tr>
<tr>
<td>Jam's responding improved over time: he initially emitted several palms-up responses in which his hands were not joined; he then responded by covering his eye(s) a couple of times; finally, in the last three trials, his up-turned palms got closer and ended up joined, thus producing the correct configuration. Cat's responding likewise improved over time: in first two trials she rubbed her hands; she then emitted many palms-up responses in which hands were not joined; she produced a correct response once, and in the following (last) trial her palms were turned up but, as earlier, not joined.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bimanual palms facing</td>
<td>Both hands extended in front of body, joined, with palms facing the experimenter (as if reading a book).</td>
<td>Nat (2)</td>
</tr>
<tr>
<td><strong>RESPONSES:</strong> Nat responded to this model incorrectly on both his trials: once with a &quot;palm point&quot; gesture, and once by reaching/pointing at the experimenter's hands.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bimanual crossed arms</td>
<td>Both arms extended in front of body, with hands fisted, clearly crossed at lower arms (with a pronounced crossing movement).</td>
<td>Jam (26) Cat (9) Gwen (6) Nat (4)</td>
</tr>
<tr>
<td><strong>RESPONSES:</strong> No child ever produced the correct response configuration.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jam's responses were quite inconsistent: his hands or fists overlapped slightly (mostly on his belly or on chair frame) without producing a crossing configuration on several early trials and also on several late trials; in the middle trials he emitted an array of incorrect responses, including tapping chair frame, touching his eye, turning his palms up, lifting his arms up, waving, and clapping. Cat's responses also included small hand overlaps that did not produce a crossing configuration: these consisted of either small hug-like gestures or hand tapping the back of her other hand. Gwen's responses were consistent small hug-like overlaps of her hands on belly. Nat's incorrect responses included a joined fist configuration, hand touches to elbow and wrist, and a bimanual head touch.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Small Hand Movements Performed Away From the Body (14 Gestures)

Tables 7.8.a, 7.8.b, 7.8.c, and 7.8.d show illustrated lists of 14 target gestures which incorporated small hand movements that were performed away from body, the descriptions of models, and of children's responses. These tables show that

- The bimanual "tiger clawing" gesture, presented to four children, appeared to have been an established matching relation for at least some children; it was certainly well trained (to include growling that was not modelled) and reliably matched for Nat, at his younger age (in probing that was presented at 18 months).

- The bimanual "duck bill clapping" gesture, presented to one child, was not a matching relation for him; he emitted various incorrect responses that contained components (e.g. hands joined, movement) similar to those present in the modelled gesture.

- The bimanual "fists banging" gesture, presented to one child, was an established matching relation for her.

- The unimanual "thumb up" gestures, modelled with the right hand for three children and with the left hand for one child, were not matching relations for any child; it appeared that complementary, non-matching responses of pointing / reaching, accompanied by giggling, were well
established for this model for at least two of the children (Nat and Gwen).

- The bimanual "thumbs up" gesture, presented to three children, was not a matching relation for any child; the model evoked incorrect responses that resembled it in some way and that varied between children (e.g. pointing, fisted hands).

- The unimanual "hand v-wiggle" gestures, modelled with the right hand for one child and with left hand for one child, were established matching relations for both children.

- The bimanual “cross-wrist wiggling” gesture, presented to four children, was not an established matching relation for these children, whose responses showed imperfect integration of the two related component gestures: hands crossing evoked small overlaps of hands (often hug-like), and fingers wiggling evoked smaller hand twitching or larger open/close hand movements.

- The bimanual “joined wiggling” gesture, presented to one child, was not a matching relation for him; he reliably responded with one component gesture (finger movement with palms facing away) but without producing the other (hands joined).

- The unimanual "index circling" gesture, presented to one child, was not a matching relation for him; he emitted one component gesture (pointing) and on only one trial integrated this with an incorrect movement (waving).
• The unimanual "finger horns" gestures, modelled with the right hand for one child and with the left hand for three children, were not matching relations for any of the children; they emitted a variety of incorrect but somewhat similar responses (e.g. pointing, spreading fingers, “v” finger configurations).

• The unimanual "pinching" gesture, presented to two children, was not a well established matching relation for these children, who mostly responded with related incorrect gestures (e.g. small hand movements).
Table 7.8.a. Descriptions of models and responses for small hand movements and configurations away from body, presented as target gestures. The bracketed numbers represent numbers of trials.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands in front and lifted to eye level, palms facing the child, fingers curled (as claws), performed as slow downward movement (as if scratching).</td>
<td>Nat (13)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gwen (6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jam (5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cat (5)</td>
</tr>
<tr>
<td>RESPONSES: All children responded correctly to this target gesture on at least some of the trials; the matches for all children involved hand configurations that were somewhat different from that modelled: children's fingers were extended more than curled, with palms facing down more often than ahead.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nat's responding got worse over trials: after many correct responses, some of which were accompanied by growling vocalisations that were not modelled, he responded in the later trial with waving, touching head, and clapping. This target gesture was presented to Nat over many trials (he responded correctly) and then re-presented over several trials after a three month long interval; at this later age the correct matching response was no longer reliably evoked by modelling.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gwen's responding got better over trials: on the early trials she responded with hands in front, hovering; on the later trials she performed a slow downward movement and a clawed hand configuration, thus producing correct responses.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cat emitted small but correct responses on most of her trials. Jam did not respond to this model in his first trials, but then produced two correct responses.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hands extended in front, one palm facing up and other down, over it, joined at wrists, together performing open/close movements (as in duck bill).</td>
<td>Nat (17)</td>
<td></td>
</tr>
<tr>
<td>RESPONSES: Nat never produced correct response configuration. He did respond reliably to this model and produced many &quot;bye&quot; (open/close) movements of a single hand; he also knitted his fingers together (twitching a little) and placed one hand on back of other hand (holding and releasing).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hands in front, fisted, one on top of other and the top one banging the lower one (as for pounding).</td>
<td>Cat (2)</td>
<td></td>
</tr>
<tr>
<td>RESPONSES: Cat responded correctly on both her trials.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7.8.b. Descriptions of models and responses for small hand movements and configurations way from body, presented as target gestures. The bracketed numbers represent numbers of trials.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right hand extended in front, with fingers fisted and thumb up, facing the child.</td>
<td></td>
<td>Cat (16)</td>
</tr>
<tr>
<td>Left hand extended in front, with fingers fisted and thumb up, facing the child.</td>
<td></td>
<td>Jam (15)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gwen (13)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nat (17)</td>
</tr>
</tbody>
</table>

RESPONSES: No child produced a correct response to these targets.

Cat’s responses were predominantly reaching and/or pointing at the experimenter, but also included waving, fingers spread, fists together in front, knitted fingers, and a few “v” finger configurations in which thumb(s) and index finger(s) were extended. Jam’s responses were mainly extending fist(s), but also included fingers spread and/or wiggling, and pointing at his head. Nat responded with either left hand pointing or bimanual reaching at the experimenter; this was accompanied by giggling on many trials. All Gwen’s responses involved pointing at the experimenter, mostly with her right hand, and giggling as she did so.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands extended in front, with fingers fisted and thumbs up, facing the child.</td>
<td></td>
<td>Jam (6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cat (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nat (2)</td>
</tr>
</tbody>
</table>

RESPONSES: No child produced a correct response configuration for this target gesture.

Jam’s responses involved right hand pointing at the experimenter; Cat’s responses were both bimanual points at body parts (belly and eyes); Nat’s responses were both bimanual fisted hands slightly raised on sides of body.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right hand extended in front, palm facing the child, hand producing a “v” configuration with thumb and index finger extended and other fingers fisted, and performing a wiggle (small semicircular motion).</td>
<td></td>
<td>Nat (8)</td>
</tr>
<tr>
<td>Left hand extended in front, palm facing the child, hand producing a “v” configuration with thumb and index finger extended and other fingers fisted, and performing a wiggle (small semicircular motion).</td>
<td></td>
<td>Cat (6)</td>
</tr>
</tbody>
</table>

RESPONSES: Both children consistently produced correct hand configurations and movements on all their trials; however, two of Nat’s responses and half of Cat’s responses were bimanual.
Table 7.8.c. Descriptions of models and responses for small hand movements and configurations away from body, presented as target gestures. The bracketed numbers represent numbers of trials.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands in front with arms crossed at wrists, palms facing the experimenter, fingers joined at thumbs and spread, performing a wiggling motion.</td>
<td>Nat (16) Cat (12) Gwen (10) Jam (2)</td>
<td></td>
</tr>
</tbody>
</table>

**RESPONSES:** No child produced the exact modelled configuration.

Nat's responses were varied; most included some "bye" (open/close) movement of hand(s) and/or joining of hands. Cat did not respond on all of her trials; her responses included several hug-like hand overlaps on belly, and touching nose; two of her responses included brief hand overlaps with small "bye" (open/close) movements of fingers. Both of Jam's responses were similar to these, with hands grabbing wrists and then overlapping in his lap, fingers twitching.

Gwen's responding got better over time. In all trials her hands performed "bye" (open/close) movements; in early trials she emitted some hug-like small hand overlaps and then hands gradually extended; in the last trials her hands were in front, palms facing the experimenter, crossed at wrist, and performing open/close movement. This final configuration bore a good resemblance to the modelled gesture, not as it was modelled but as it was seen from Gwen's perspective.

| Hands in front, palms facing the child, fingers joined at thumbs and spread, performing a wiggling motion. | Nat (4) |

**RESPONSES:** Nat responded with fingers wiggling or performing "bye" (open/close) movement on three out of four trials; palms were facing the experimenter; and on the last trials his hands briefly joined after the movement was performed.

| Index finger of right hand was extended in front and pointing upwards, performing a slow circular movement. | Nat (8) |

**RESPONSES:** Nat did not respond correctly to this model. He pointed with his left hand on the early trials, responded with tapping middle of his body and a hand wave with index finger extended once, and failed to respond on the last three trials.
Table 7.8.d. Descriptions of models and responses for small hand movements and configurations away from body, presented as target gestures. The bracketed numbers represent numbers of trials.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right hand extended in front, palm facing the child, fingers curled except for index and little finger that were extended (as in making a horns sign).</td>
<td>Nat (4)</td>
<td></td>
</tr>
</tbody>
</table>
| Left hand extended in front, palm facing the child, fingers curled except for index and little finger that were extended (as in making a horns sign). | Jam (6)  
Cat (6)  
Gwen (3) |

RESPONSES: No child produced the correct hand configuration in response to this target model.

Nat responded with incorrect trained gestures: either palm points or "v" wiggles (where thumb and index fingers were extended and moved).

Jam did not always respond to this model; his responses included spreading all fingers, holding thumb and index curled and spreading the remaining fingers, and curling all fingers except for thumb and index (in a "v" configuration). In one of his trials Jam produced a correct "nose wiggle" configuration, which he never emitted to the corresponding model (see next heading).

All Cat's responses were pointing and reaching.

All Gwen's responses involved spreading fingers in front and looking at them.

Right hand in front and slightly lifted, pinching movement was performed repeatedly with index finger and thumb, as hand moved about. | Nat (8)  
Cat (4) |

RESPONSES: One of two children emitted a single correct response to this target gesture.

Cat consistently responded with hand extended and fingers moving a little, but without forming a pinching configuration.

Nat did not reliably respond to this model; his responses included small "bye" (open/close) hand movements and reaching. He performed one correct response but in the following trials this was not repeated.
Small Hand Movements Performed on Body Parts (13 Gestures)

Tables 7.9.a, 7.9.b, and 7.9.c, show illustrated lists of 13 target gestures which incorporated small hand movements that were performed on (touched) body parts, the descriptions of models, and of children's responses. These tables show that

- The unimanual and bimanual "nose point" gestures, modelled with the right hand for four children, with the left hand for one child, and with both hands for three children, were well established matching relations for all children; unimanual models evoked the correct response configurations more reliably than bimanual ones.

- The unimanual "nose wiggle" gestures, modelled with the right hand and with the left hand for all four children, were not established matching relations for any of the children. All children appeared unable to fully integrate the two component gestures: thumb touching nose and hand wiggling. Thus nose wiggle target gestures evoked either pointing at face locations (e.g. touching nose and cheek with the index finger) or small hand movements (open/close “bye” gesture). The closest that the children came to emitting these component gestures together was performing a “bye” movement close to face (and perhaps briefly touching a cheek).

- The unimanual "fist to temple" gestures, modelled with the right hand for one child and with the left hand for three children, were not
established matching relations for any of the children; children mainly emitted similar, "fist to cheek" responses.

- The bimanual "horns" gesture, presented to four children, was not an established matching relation for the children, three of whom consistently responded with the similar "face point" gestures; the remaining child (Gwen) developed correct matching responses over trials.

- The bimanual "ear point" gesture, presented to one child, was not a matching relation for this child, who emitted an array of similar but incorrect gestures (e.g. touching chin, mouth, cheeks).

- The bimanual and unimanual "ear pull" gestures, modelled with both hands and with the left hand for one child, were not matching relations for this child, who emitted related, incorrect responses (e.g. ear touches).

- The bimanual "head frame" gesture, presented to one child, was either an established matching relation for this child, or she may have developed correct responding quickly, within the trials.

- The unimanual "mimed drinking" gesture, modelled with the right hand to one child, was an established matching relation for this child.
**Table 7.9.a.** Descriptions of models and responses for small hand movements and configurations that touched body, presented as target gestures. The bracketed numbers represent numbers of trials.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right nose point</td>
<td>Index finger of right hand touching nose.</td>
<td>Jam (6)</td>
</tr>
<tr>
<td></td>
<td>Index finger of left hand touching nose.</td>
<td>Nat (4)</td>
</tr>
<tr>
<td></td>
<td>Index fingers of both hands touching nose.</td>
<td>Cat (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gwen (2)</td>
</tr>
</tbody>
</table>

**RESPONSES:** All children emitted at least some correct matching responses to these target gestures.

Jam did not respond on the first half of his trials; he then consistently responded correctly. Nat's responses were consistently correct, performed mostly with a mirror hand to unimanual models and bimanually to bimanual ones. Cat's responses were also consistently correct to unimanual models but her responses to bimanual models were performed unimanually (except on her first trial, where she responded correctly). Gwen's responses to unimanual models were both correct; her responding to bimanual responses improved over trials. She initially responded by bringing her hands with all her fingers spread to nose, but then emitted several correct responses with only indices extended to touch nose.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left nose point</td>
<td>Right hand thumb touching tip of nose, fingers wiggling.</td>
<td>Jam (22)</td>
</tr>
<tr>
<td></td>
<td>Left hand thumb touching tip of nose, fingers wiggling.</td>
<td>Cat (17)</td>
</tr>
</tbody>
</table>

**RESPONSES:** No child produced the exact correct response configuration for these target gestures.

Jam's responding to these models developed from "nose points" (index finger touching nose), "bye" (open/close) hand movements, and touches to face, to reliable and consistent picking of nose (with his right hand). Most of Cat's responses involved making small "bye" movement with (mostly right) hand in front and slightly up; on one of the trials she vocalised "bye-bye" as she did so. Cat also emitted some "nose points" and unrelated baseline responses ("tongue protrusion"). She performed a single response that was close to correct: hand opening and closing so close to face that the side of her nose was touched (although not with an extended thumb); however, this was not repeated in the later trials. Most of Nat's responses were "bye" (open/close) movements of a single hand, performed close to face; in doing so he often touched his cheek (and on one trial side of nose). His other responses included touching face, head, and nose. Most of Gwen's responses were also "bye" (open/close) hand movements performed in front and side; some of these were close to her face and at least one touched a cheek.
**Table 7.9.b.** Descriptions of models and responses for small hand movements and configurations that touched body, presented as target gestures. The bracketed numbers represent numbers of trials.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fisted right hand touching temple.</td>
<td>Gwen (2)</td>
</tr>
<tr>
<td></td>
<td>Fisted right hand touching temple.</td>
<td>Jam (7)</td>
</tr>
<tr>
<td></td>
<td>Fisted right hand touching temple.</td>
<td>Nat (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cat (4)</td>
</tr>
<tr>
<td>Right hand fist to temple</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fisted hands placed on temples with index fingers sticking up (as in making horns).</td>
<td>Nat (16)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jam (12)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gwen (10)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cat (6)</td>
</tr>
<tr>
<td>Left hand fist to temple</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bimanual horns</td>
<td></td>
</tr>
</tbody>
</table>

RESPONSES: Only one child produced the exact correct response configuration.

- Gwen, Nat, and Cat consistently responded by placing a fist on their cheeks.
- Jam's initial responses were similar, but over trials he also emitted several fist-touches to eye and temple (correct).

RESPONSES: Only one child performed the exact correct responses.

- Nat consistently responded to these models by pointing at his cheeks, eyes, neck, temples, and the experimenter.
- Jam's responses were also points, mostly at forehead/temples.
- Cat's responses were not entirely correct, but her indices did point upwards as she touched her cheeks, face, and eyes.
- Gwen's responding improved over trials: she pointed at her neck, then face, and then forehead; her indices were initially pointing down but then started turning upwards. In the final trials she emitted entirely correct responses; these were performed progressively faster and more assuredly; she also held the correct configuration in place for long after the modelling stopped.
Table 7.9.c. Descriptions of models and responses for small hand movements and configurations that touched body, presented as target gestures. The bracketed numbers represent numbers of trials.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bimanual ear point</td>
<td>Index fingers of both hands touched ears.</td>
<td>Jam (14)</td>
</tr>
<tr>
<td>Bimanual ear pull</td>
<td>Indices and thumbs of both hands pinched ears and pulled them outwards.</td>
<td>Nat (2)</td>
</tr>
<tr>
<td>Bimanual ear pull</td>
<td>Left index and thumb pinched ear and pulled it outwards.</td>
<td>Nat (4)</td>
</tr>
<tr>
<td>Bimanual head frame</td>
<td>One hand was placed on chin and the other one on top of head; both palms faced down.</td>
<td>Cat (2)</td>
</tr>
<tr>
<td>Right hand cup/drinking</td>
<td>Right hand was curled (as if holding a cup) and moved slowly to mouth, head tilted backwards (as if drinking).</td>
<td>Cat (2)</td>
</tr>
</tbody>
</table>

RESPONSES: Jam produced a correct gesture only once, in an early trial; the remaining responses included indices touching cheeks, chin, and mouth; he also performed some unimanual "palm points" and touched face with whole hands.

RESPONSES: Nat never performed an exactly correct response configuration to these models. He responded with "ear points" (index finger touching ear) and/or "ear touches" (whole hand touching ear) to unimanual models, and with placing fists or pointing at eyes to bimanual models.

RESPONSES: Cat's responding developed within the first trial from hand on head, to hand on chin, to hands on both head and chin; this correct response was also emitted on her second trial.

RESPONSES: Nat responded with correct hand configurations and head tilt to both his models; on the first trial both hands were used, and on the second only right hand was used, producing the correct response.
Hand-To-Body Gestures (1): Ear, Shoulder, Knee, and Foot Touches

Hand touches to the ear, shoulder, knee, and foot were modelled as (i) ipsilateral touches, where a hand touched a body part on the same side, without crossing the midline, and (ii) contralateral touches, where a hand crossed the midline of the body and touched a body part on the other side. These touches were all modelled with the right hand and with the left hand, thus creating a set of 16 gestures, all of which were presented to all children, across a minimum of 5 trials per gesture per child. This facilitated more comprehensive analyses of the regularities and the differences between individual children’s matching of upper and lower body touches.

All target touches to ear, shoulder, knee, and foot are listed and illustrated in Tables 7.10.a, 7.10.b, 7.10.c, and 7.10.d. Children’s responses, described in these tables, showed that

- The ipsilateral “ear touches” were well established matching relations for all children.

- The contralateral “ear touches” were not matching relations for most children, who responded with similar, ipsilateral touches; only one child (Gwen) matched these gestures well on most of her trials.
The ipsilateral “shoulder touches” were matching relations for all children, although they all occasionally responded by touching incorrect body parts.

The contralateral “shoulder touches” were not matching relations for most children; all children responded with similar, ipsilateral touches on most of their trials, and some also emitted small hug-like responses; only one child (Cat) matched these gestures on a small proportion of her trials.

The ipsilateral “knee touches” were well established matching relations for all children; only one child (Gwen) emitted incorrect contralateral knee touches on some of her trials.

The contralateral “knee touches” were not matching relations for most children; all children responded with similar, ipsilateral touches; only one child (Gwen) produced correct ipsilateral knee touches on many of her trials.

The ipsilateral “foot touches” were well established matching relations for all children.

The contralateral “foot touches” were not matching relations for most children, who responded with similar, ipsilateral touches; only one child (Gwen) matched these gestures well on most of her trials, and one other child (Nat) emitted a couple of correct contralateral foot touches.
Table 7.10.a. Descriptions of models and responses for hand-to-ear target gestures, presented to all children. The bracketed numbers represent numbers of trials on which the right-handed (first number) and the left-handed (second number) models were presented, for ipsilateral (upper half of table) and contralateral (lower half of table) target gestures.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right hand to ipsilateral ear</td>
<td>Right hand touches (and in doing so covers) ipsilateral ear.</td>
<td>Nat (6+6)</td>
</tr>
<tr>
<td></td>
<td>Left hand touches (and in doing so covers) ipsilateral ear.</td>
<td>Gwen (6+6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cat (6+6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jam (6+6)</td>
</tr>
<tr>
<td>RESPONSES: All children produced correct response configurations on most or all of their trials.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>In many of these responses children touched their cheeks and/or temples; this was coded as correct because the experimenter’s hand also covered not just ear but the whole side of her face (see illustrations).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All children’s responses were predominantly right handed.</td>
<td></td>
</tr>
<tr>
<td>Left hand to ipsilateral ear</td>
<td>Right hand touches (and in doing so covers) contralateral ear; its movement crosses body midline.</td>
<td>Nat (6+7)</td>
</tr>
<tr>
<td></td>
<td>Left hand touches (and in doing so covers) contralateral ear; its movement crosses body midline.</td>
<td>Gwen (6+6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cat (7+6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jam (6+6)</td>
</tr>
<tr>
<td>RESPONSES: Only one child produced correct response configurations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gwen responded correctly on most of her trials; most of her responses were right handed.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The remaining children responded with ipsilateral ear touches on most of their trials; Cat and Jam emitted unimanual responses, and Nat emitted mostly bimanual responses, especially to left hand models.</td>
<td></td>
</tr>
</tbody>
</table>
Table 7.10.b. Descriptions of models and responses for hand-to-shoulder target gestures, presented to all children. The bracketed numbers represent numbers of trials on which the right-handed (first number) and the left-handed (second number) models were presented, for ipsilateral (upper half of table) and contralateral (lower half of table) target gestures.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right hand to ipsilateral shoulder</td>
<td>Right hand touches or taps ipsilateral shoulder.</td>
<td>Nat (6+10) Gwen (6+6) Cat (6+6) Jam (6+6)</td>
</tr>
<tr>
<td>Left hand to ipsilateral shoulder</td>
<td>Right hand touches or taps ipsilateral shoulder.</td>
<td></td>
</tr>
</tbody>
</table>

**RESPONSES:** All children produced correct response configurations on most of their trials.

All children also touched parts of body other than shoulders (their cheeks, head, and/or temples).

Left handed models evoked better responding than the right hand ones for all children. All children’s responses were predominantly right handed.

| Right hand to contralateral shoulder | Right hand touches or taps contralateral shoulder; its movement crosses body midline. | Nat (12+6) Gwen (10+18) Cat (24+6) Jam (14+24) |
| Left hand to contralateral shoulder | Left hand touches or taps contralateral shoulder; its movement crosses body midline. |  |

**RESPONSES:** Only one child produced correct response configurations.

Cat responded correctly on a small proportion of her trials; most of her responses were ipsilateral shoulder touches.

The remaining children also responded with ipsilateral shoulder touches on most of their trials.

All children also touched parts of body other than shoulders (cheeks, head, knee); some of their incorrect responses involved small arm touches or hug-like overlaps. All children emitted some bimanual ipsilateral responses, especially to left handed models.
Table 7.10.c. Descriptions of models and responses for hand-to-knee target gestures, presented to all children. The bracketed numbers represent numbers of trials on which the right-handed (first number) and the left-handed (second number) models were presented, for ipsilateral (upper half of table) and contralateral (lower half of table) target gestures.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
</table>
| Right hand to ipsilateral knee | Right hand touches or taps ipsilateral knee. | Nat (6+6)  
Gwen (6+6)  
Cat (6+6)  
Jam (6+6) |
| Left hand to ipsilateral knee | Left hand touches or taps ipsilateral knee. | |
| Right hand to contralateral knee | Right hand touches or taps contralateral knee; its movement crosses body midline. | Nat (6+6)  
Gwen (6+6)  
Cat (6+6)  
Jam (6+6) |
| Left hand to contralateral knee | Left hand touches or taps contralateral knee; its movement crosses body midline. | |

RESPONSES: All children responded with correct configurations on most or all of their trials.

Many of children’s responses involved touching mid-leg, just above knee; these were coded as correct: the exact touches were somewhat difficult to emit because the chair frame often stood in children’s way.

Three children responded almost solely with their right hands; the remaining child (Nat) responded mostly with his left hand.

Only one child, Gwen, emitted contralateral knee touches to some of these models. Nat and Jam emitted several bimanual ipsilateral knee touches each.

RESPONSES: Only one child produced correct response configuration.

Gwen emitted correct or mirror responses on all of trials where modelling was left-handed, but emitted incorrect, ipsilateral knee touches on all of her trials where modelling was right handed.

The remaining three children emitted ipsilateral knee touches on most or all of their trials; they also emitted a few bimanual responses each.

Only Nat touched incorrect body parts (foot, chest) on some of his trials.
**Table 7.10.d.** Descriptions of models and responses for hand-to-foot target gestures, presented to all children. The bracketed numbers represent numbers of trials on which the right-handed (first number) and the left-handed (second number) models were presented, for ipsilateral (upper half of table) and contralateral (lower half of table) target gestures.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
</table>
| Right hand to ipsilateral foot | Right hand touches or taps ipsilateral foot. | Nat (5+6)  
Gwen (6+6)  
Cat (6+6)  
Jam (6+6) |
| Left hand to ipsilateral foot | Left hand touches or taps ipsilateral foot. |  |
| Right hand to contralateral foot | Right hand touches or taps contralateral foot; its movement crosses body midline. | Nat (6+6)  
Gwen (6+6)  
Cat (6+6)  
Jam (6+6) |
| Left hand to contralateral foot | Left hand touches or taps contralateral foot; its movement crosses body midline. |  |

**RESPONSES:**

- All children produced correct response configurations on most or all of their trials.
- Three children’s responses were predominantly right handed; the remaining child (Nat) emitted predominantly left handed responses.
- Nat and Jam emitted a few bimanual responses to these models. Only Cat touched incorrect body parts (her thighs) on two of her trials.
- Only two children produced correct response configurations.
  - Gwen responded correctly on most of her trials; the remaining responses were ipsilateral foot touches; most of her responses were right handed. Nat emitted one correct and one mirror response.
  - Three children (Nat, Cat, and Jam) responded with ipsilateral foot touches on most of their trials. Only Cat touched incorrect body parts (her knee and elbow) on two of her trials.
Figure 7.10 shows the percentages of trials in which children emitted correct and mirror responses, across ipsilateral and contralateral touches.

Figure 7.10. Percentages of trials in which correct (red bars) and mirror (blue bars) responses were emitted, for all children, across ipsilateral (upper graph) and contralateral (lower graph) touches to ear, shoulder, knee, and foot.
All children emitted mirror responses more frequently than the correct ones. Only one child (Gwen) responded with good contralateral matches to the appropriate models on a substantial proportion of her trials; the remaining children emitted few if any such responses.

Across all contralateral trials, children's most frequent errors involved touching the correct body parts with incorrect, ipsilateral movements. Figure 7.11 shows percentages of trials in which children (i) responded with ipsilateral touches to contralateral models (ipsi-for-contra errors), and (ii) responded with contralateral touches to ipsilateral models (contra-for-ipsi errors), across all ear, shoulder, knee, and foot target gestures.

Overall, children emitted ipsi-for-contra errors equally frequently across all target groups. Within children, Gwen committed the fewest such errors (she had none across ear gestures), and Jam committed the most such errors (he emitted ipsilateral responses to contralateral models on all trials for knee and foot gestures).

The reverse errors—contralateral responses to ipsilateral models (contra-for-ipsi errors)—were emitted only infrequently, and by only two children (Cat and Gwen).
Figure 7.11. Percentages of trials for ear, shoulder, knee, and foot target gestures in which children emitted: (i) ipsilateral touches to contralateral models (ipsi-for-contra errors, shown in the upper graph), and (ii) contralateral touches to ipsilateral models (contra-for-ipsi errors, shown in the lower graph), for Nat (red bars), Gwen (blue bars), Cat (yellow bars), and Jam (green bars).

Children's errors also involved touches to incorrect body parts; these were not very frequent, yet all children committed them on some of their
trials. Figure 7.12. shows the percentages of all trials in which children touched incorrect body parts, across ear, shoulder, knee, and foot target gestures. Across all children, Nat emitted the most responses in which incorrect body parts were touched; across all target gestures, most such errors were committed on hand-to-shoulder touches.

![Graph showing percentages of trials for ear, shoulder, knee, and foot target gestures in which children touched incorrect body parts.]

**Figure 7.12.** Percentages of trials for ear, shoulder, knee, and foot target gestures in which children touched incorrect body parts, for Nat (red bars), Gwen (blue bars), Cat (yellow bars), and Jam (green bars).

All the children responded bimanually to hand-to-body target gestures, all of which were modelled unimanually, on at least some of the trials. Figure 7.13. shows the percentages of all trials in which children touched correct body parts but used both hands to do so, across ear, shoulder, knee, and foot target gestures. Across all children, Nat emitted the most bimanual responses, especially to ear and shoulder models; across all target
gestures, the fewest such errors were committed on hand-to-foot touches.

![Figure 7.13. Percentages of trials for ear, shoulder, knee, and foot target gestures in which children touched correct body parts but used both hands to do so (bimanual-for-unimanual errors), for Nat (red bars), Gwen (blue bars), Cat (yellow bars), and Jam (green bars).]
Hand-To-Body Touches (2): Underside-Of-Arm Touches to Elbow and Wrist (Four Gestures)

Hand touches to elbow and wrist were all modelled as touches to underside-of-arm surface: the experimenter lifted her arm-to-be-touched and bent it upwards, and then touched either her wrist or elbow. All these touches were modelled with the right hand and with the left hand, thus creating a set of four gestures, each of which was presented to all children across a minimum of five trials per gesture per child.

All target touches to elbow and wrist are listed and illustrated in Table 7.11. Children's responses, presented in this table, showed that

- The underside-of-arm “elbow touches” were matching relations for two children (Cat and Gwen), who produced the correct response configurations on most of their trials, but not for the remaining two children (Nat and Jam), who responded by tapping the backs of their hands on most of the trials.

- The underside-of-arm “wrist touches” appeared to be matching relations for two children (Cat and Gwen), who produced the correct response configurations on some of their trials, and emitted either elbow touches or top-of-arm wrist touches on their remaining trials. These target gestures were not matching relations for the remaining two children (Nat and Jam), who responded on most of the trials with top-of-arm touches, a majority of which were to wrist/backhand.
Table 7.11. Descriptions of models and responses for hand-to-elbow and hand-to-wrist target gestures, presented to all children. The bracketed numbers represent numbers of trials on which the right-handed (first number) and the left-handed (second number) models were presented, for elbow (upper half of table) and wrist (lower half of table) target gestures.

<table>
<thead>
<tr>
<th>Target Gesture</th>
<th>Description of Models</th>
<th>Target for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right hand to elbow</td>
<td>Right hand touches or taps left elbow; arm-to-be-touched bent and lifted; touch on underside-of-arm surface.</td>
<td>Nat (6+5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gwen (6+6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cat (6+6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jam (6+6)</td>
</tr>
<tr>
<td>Left hand to elbow</td>
<td>Left hand touches or taps right elbow; arm-to-be-touched bent and lifted; touch on underside-of-arm surface.</td>
<td></td>
</tr>
<tr>
<td>Right hand to wrist</td>
<td>Right hand grabs or taps left wrist; arm-to-be-touched bent and lifted; touch on underside-of-arm surface.</td>
<td>Nat (6+6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gwen (5+6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cat (7+5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jam (6+6)</td>
</tr>
<tr>
<td>Left hand to wrist</td>
<td>Left hand grabs or taps right wrist; arm-to-be-touched bent and lifted; touch on underside-of-arm surface.</td>
<td></td>
</tr>
</tbody>
</table>

RESPONSES: Only two children produced correct response configuration.

Gwen responded with elbow touches on most of her trials; her responses were predominantly right handed. Cat emitted elbow touches on just over half of her trials; her responses were predominantly left handed.

All Nat’s and Jam’s responses were touches to top-of-arm surface (arm-to-be-touched was not lifted or bent); most involved tapping back of hand/wrist and not middle-arm/elbow. Cat’s and Gwen’s errors were also of this type.

Gwen and Cat responded with correct wrist touches on some of their trials; their incorrect responses were either underside-of-arm touches to elbow or top-of-arm wrist touches.

All Nat’s and Jam’s responses were incorrect; most of these involved touches to top-of-arm surface (arm-to-be-touched was not lifted or bent) and tapping back of hand/wrist.
Figure 7.14 shows the percentages of trials in which children emitted correct and mirror responses, and the three most frequent types of incorrect responses (top-of-arm touches to wrist, top-of-arm touches to elbow, and underside-of-arm touches to elbow emitted to wrist models), across all hand-to-elbow and hand-to-wrist target trials.

Figure 7.14. Percentages of all hand-to-elbow and hand-to-wrist target trials in which children emitted correct and mirror responses (red bars), and percentages of trials in which children emitted incorrect responses, including: underside-of-arm touches to elbow emitted to wrist models (blue bars), top-of-arm touches to elbow/mid-arm (yellow bars), and top-of-arm responses to wrist/backhand (green bars).
As can be seen from Figure 7.14, Cat and Gwen emitted underside-of-arm touches to elbow and wrist on most of their trials; a majority of these responses were correct or mirror. Mirror and correct responses were emitted on an equal proportion of trials for these two participants, because they showed strong hand preferences for elbow and wrist touches; Gwen mostly responded with her right hand, and Cat with her left hand. Both girls responded with underside-of-arm elbow touches to wrist models but not vice versa; they emitted very few top-of-arm touches.

By contrast, Nat and Jam never emitted any underside-of-arm touches, and thus had no correct or mirror responses. They responded on virtually all their trials with top-of-arm touches, the majority of which were on wrist or back of hand, especially for Nat.

The remaining incorrect responses, not pictured in Figure 7.15, consisted of four bimanual “crossed wrists” for Nat, a single “palm point” for Gwen, two trials with no responses for Cat, and a single trial of “clapping” for Jam.
DISCUSSION

The matching repertoires of four children, under two years old, were found in the present study to contain a multitude of gestural matching relations. Over most target gestures, matching performances were comparable between children; over many remaining gestures, the two girls (Cat and Gwen), who were slightly older than the two boys (Nat and Jam), showed comparably more consistent and better matching. Overall, Gwen's matching performance was superior to that of her peers.

The present experiment employed a design similar to that of several behaviour analytic studies that professed to investigate generalised imitation in children and infants (e.g. Baer & Sherman, 1964, Poulson & Kymississ, 1988). Participants were presented with two sets of gestures:

1. Trained (baseline) sets contained four gestures per child; children's correct matching responses to baseline (trained) gestures received intermittent reinforcement.

2. Target sets contained over 40 gestures per child; these were presented in subsets of 4 and 5 gestures per session; children's responses to target gestures were neither reinforced nor corrected.

As discussed in Chapter 3, the authors of the earlier behaviour analytic studies commonly inferred that children's matching of target behaviours demonstrated their higher-order matching (imitation) abilities. However, it was argued that this inference was not warranted: without
knowledge of the complete training histories of all participants, direct extra-experimental operant training has to be considered as the most likely and most parsimonious explanation for the apparently emergent correct matching of target gestures in an experiment.

**Generalisation of Trained Matching**

Children's matching of target gestures in the present study was, over most gestures and children, consistent with generalisation—along the lines of similar topography—of trained matching to modelling presented by a new social partner in the experimental setting.

For most target and baseline gestures children either responded with correct matching straight away, and continued to respond so over trials, or responded incorrectly and did not improve over trials, although variability in their responding was often high. Successive approximations to correct responses were seldom enough noted for three out of four children (Nat, Cat, and Jam) as to have been emitted by chance. This is consistent with generalisation of trained matching: any given target gesture was either an established discriminative stimulus for an extra-experimentally trained matching responses (in which case children consistently emitted correct responses), or it had no such history (in which case children consistently emitted incorrect responses).

In a good demonstration of generalisation of extra-experimentally trained responding, Nat's responses to bimanual "tiger" models contained the additional "growling" vocalisations that were obviously trained as a
component of this matching relation, but were not modelled in the experiment. Nat’s responses to this target gesture showed that “tiger” was a well-established matching relation at an earlier age, but not at an older age (the model was re-presented after a four month break). As discussed in Chapter 3, children’s trained matching repertoires are expected to change over time: overall, they would be expected to grow, but also to occasionally “lose” gestures when some of the “old” games are no longer played.

Children’s incorrect responses, in most cases, resembled in some way those modelled to them. Children frequently emitted the same (presumably trained) responses to several different target models. For example, Nat performed "bye" movements to: bimanual cross-wristed wiggling models (in which hands were crossed at wrists, thumbs joined, palms faced the experimenter, and fingers wiggled), bimanual joined wiggling models (in which thumbs were joined, palms facing the child, and fingers wiggled), unimanual pinching models (in which thumb and index finger made a pinching movement and moved about), bimanual duck-bill models (in which palms were joined at wrist, placed horizontally, and opened/closed), and unimanual nose wiggle models (in which thumb touched nose and fingers wiggled), all of which contained movements that were similar to the well-established (trained) open/close "bye" gesture.

Children frequently emitted several different (presumably trained) gestures in response to modelling of a target gesture, across and within trials. Thus Cat responded to "arm across forehead" models, in which the fisted right arm was positioned in front and the head was lowered until the forehead rested on the lower arm, by placing her fist on the eye, cheek, or
mouth. Jam responded to "hand circling" models, in which a hand with palm facing the child was lifted slightly in front and performed slow circular movements, by lifting his hand(s) up, and by waving. Nat responded to "finger horns", in which index and little finger of one hand were extended in a horn-like configuration, by palm point gestures (index finger touched palm), and by "v" wiggle gestures (index and thumb extended and wiggling). Gwen responded to "hand to wrist" models, in which arm-to-be-touched was bent up and wrist grabbed, by tapping the top of her wrist without lifting or bending her arm, and by tapping her elbow.

All the above responses are consistent with generalisation of trained matching: target gestures that were not trained matching relations usually contained one or more physical features that were similar to those of other trained matching relations, and thus evoked one or more corresponding but incorrect trained responses.

Complementary, non-matching responses were emitted to at least one of the target gestures: in response to "thumb up" models all children reached or pointed at the experimenter's hand; they giggled as they did so on many trials. This is consistent with generalisation of trained responding, which in this case involved non-matching gestures and vocalisations, probably established in a conventional game (with which the experimenter was not familiar).
Chapter 7

Experiment 2

**Trained Response Integration**

Children's matching of several complex gestures, which consisted of two or more components that were themselves established matching relations, indicated that—across most gestures—children cannot integrate such responses well. For example

- Unimanual "nose wiggle" gestures, consisted of (i) touching the nose with a thumb (this resembled an established matching relation performed with index fingers, "nose point"), and (ii) fingers wiggling (this evoked the less pronounced "bye" hand movements across all gestures of which it was a part). These target gestures evoked responses that showed poor integration of the two components: across most trials, children either touched their face, or made small "bye" hand movements; at best, and over few trials, children produced "bye" hand movements near their faces.

- Bimanual "flying" models consisted of (i) spreading arms wide (an established matching relation, "allgone") and (ii) large up/down movement (an established matching relation when performed in front of the body, "waving"). These target gestures evoked responses that showed some integration of the two components; however, all children's gestures were less expansive (arms were extended more to front than to side) than the corresponding target models. A similar pattern was seen with the related, bimanual "side circle" target gesture, presented to one child.

- Bimanual "up/down joined" models consisted of (i) joined hands (that all
children emitted to many of their models) which were (ii) performing a large up/down movement (an established matching relation done with separated hands, "waving"). This target gesture evoked correct responses emitted reliably and without fumbling for one child (Gwen), correct responses emitted reliably after self-correction within trials for one child (Cat), and occasional correct responses with incorrect (component) responses emitted on most trials for the remaining two children (Nat and Jam).

Overall, it appears that children probably responded to novel combinations of trained gestures through generalisation of trained matching; in Skinner's (1957) terminology, they were combining behaviours from their "minimal response repertoires". Doing so did not in itself require higher-order matching abilities, unless major adjustments to the component gestures needed to be made in order to achieve the component response integration (and see discussion of "novelty" in Chapter 1). In the present experiment, children showed little evidence of such adjustments: they all performed better to the gestures that required little or no modification of their trained components (e.g. "up/down" joined) than they did to those gestures that required more modification of their components (e.g. "nose wiggle").

**Perceptual Tethering (Following the Experimenter's Movement)**

It appeared that children matched some of the gestures that involved large arm movements (e.g. unimanual "hand circle" and bimanual "hands treading") by reaching forth and then following the experimenter's
movement as it was modelled. Such “perceptual tethering” or tracking may have been trained as a game or a part of a game. It always (necessarily) produced mirroring of the target gestures; for example, “hand circle” models were presented as slow clockwise movements, and the children’s responses were slow anti-clockwise movements that occurred in synchrony with the experimenter’s movement.

**Hand Preferences, Correct vs. Mirror Responding, and Unimanual vs. Bimanual Responding**

Three out of four children showed marked preferences for right handed responding and the remaining child (Nat) responded with his right and left hand on about equal proportions of trials. Across all target gestures, two participants (Gwen and Nat) also showed a preference for responding in the same space as the experimenter (mirroring); they emitted (i) comparably more left handed responses to the right hand models than to the left hand ones, and (ii) comparably more right handed responses to the left hand models than to the right hand ones. The remaining two participants’ responding was apparently unaffected by which hand the experimenter used for modelling.

For hand-to-body touches, which were modelled to all children towards the end of the study (and hence at comparably older ages), all children emitted mirror responses slightly more often than the correct ones. This tendency was very strong only for Gwen. It has been reported that, in similar matching tasks, older children emit predominantly mirror responses (Bekkering et al., 2000, and see next chapter); overall, most
of the younger participants in the present study showed only a weak
tendency in this direction.

Across all target gestures, bimanual responses to unimanual models and
unimanual responses to bimanual models were not very frequent; across
all children, Nat emitted most such errors. Two children (Nat and Gwen)
emitted bimanual responses to unimanual models more often than vice
versa; a slight opposite trend was noted for Jam, whose predominantly
right handed responding extended to many of the bimanual models; Cat
emitted bimanual responses to unimanual models about equally
frequently as vice versa. Thus, over all target gestures, children showed no
strong preferences for bimanual or for unimanual responding.

**Hand Touches to Body**

Hand touches to ear, shoulder, knee, foot, elbow, and wrist were modelled
as (i) contralateral touches, in which a hand had to cross the body midline
in order to touch a body part, and (ii) ipsilateral touches, which were
performed on the same side of body. These gestures were modelled with the
right hand and with the left hand. The sets of 16 gestures were presented
to all children, with five or more trials per gesture per child.

The ipsilateral hand-to-body touches feature in conventional matching-
and-naming games; they are often performed bimanually. The ipsilateral
touches to ear, shoulder, knee, and foot were therefore more likely to be
established matching relations than were the contralateral hand-to-body
touches, which had no such training history.

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Children’s responses to hand-to-body target gestures were consistent with generalisation of trained matching. Thus:

- Children showed very poor matching of contralateral (uncommon) gestures, and good matching of ipsilateral (common) gestures.

- Children’s incorrect responses to contralateral (uncommon) models mostly consisted of ipsilateral (common) responses; the reverse errors were seldom if ever observed.

- The remaining incorrect responses contained some touches to incorrect body parts, especially for shoulder models; they also contained some bimanual touches of correct body parts (Nat performed these frequently). Most of these errors probably contained common responses to comparably uncommon models. A naming-and-matching game much used in the Nursery from which the present participants were recruited—“heads and shoulders, knees and toes”—goes thus: touches to several body parts are performed in a sequence, and modelling is done bimanually.

**Hand Touches to Arm**

All elbow and wrist touches were performed on the underside-of-arm surface, with the arm-to-be-touched bent up and lifted. The elbow touches resembled gestures commonly used in matching-and-naming games (for naming “elbow”); some of the participants could have been exposed to such games. The wrist touches had no such training history.
Children's responses to hand touches to arm were consistent with generalisation of trained matching. Thus:

- Across elbow and wrist target gestures, only two participants emitted some correct and mirror responses; the naming game for "elbow" was apparently not trained for all children. The same two children emitted elbow touches (common) to wrist models (uncommon), but never vice versa.

- The remaining incorrect responses (virtually all responses for two children) were tapping the top-of-arm surface; most of these touches were to wrist and backhand (this was a common trained response that all children emitted to models that contained crossing arms or body midline).

**Children's Vocalisations and Naming**

As noted for hand-to-body touches, many conventional matching games that are trained to children also contain naming (e.g. of body parts) and other vocalisations (e.g. animal noises). Thus a modelled behaviour presented in an experiment may evoke both a gestural response and a vocalisation, which may be emitted simultaneously. As discussed earlier, this happened when Nat was presented with the bimanual "tiger" models; he often emitted "growling" vocalisations, which were not modelled.

As discussed in Chapter 3, naming of gestures or parts of gestures may be functional in children's responding to models in an experiment.
Modelled behaviour may evoke a name, which in turn may control a gestural response; in such episodes children's naming may remain covert. It is not possible to establish how much of children's matching was thus determined in the present study; the children did not overtly name gestures (movements or body parts). All children were under two years old throughout Condition 3 probing, and Griffiths' testing revealed that they did not have large naming repertoires; however, matching-through-naming remains a possibility for at least some of the conventional gestures that were modelled in the experiment.

**Higher-Order Matching (Imitation)**

As discussed in Chapter 3, higher-order matching refers to emergent matching of entirely novel modelled behaviours that can be established without external reinforcement. Those of children's varied responses that resemble the seen model's behaviour are said to be reinforced by the similarity (parity) that they achieve.

The performances of three children (Nat, Jam, and Cat) were not consistent with higher-order matching. Thus:

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2 There was only one such instance: Cat incorrectly emitted a "bye" response to a "nose wiggle" model, and said "bye-bye" as she gestured. In this episode, it is possible that (i) the modelled gesture evoked naming, which in turn evoked the corresponding hand movement, or (ii) the modelled gesture evoked both naming and the hand movement, or (iii) the modelled gesture evoked the hand movement which in turn evoked naming.
Children's unreinforced responding to target models remained consistent over time for most gestures; it got better and worse on about equal proportions of the remaining gestures. Within trials where more than one response were emitted, all the children got better more often than they got worse. However, such "improvements" were slight, mostly consisting of two incorrect, trained, and well-established responses, the first of which bore little or no resemblance to the modelled gesture, and the second of which was still not correct. For example, when presented with an unimanual "thumb up" model a child responded with bimanual reaching, and then with unimanual reaching or pointing. Both responses were incorrect, but the second one was coded as a closer approximation to the target, which contained a unimanual hand extension; the trial was then coded as improving. Over the later trials such "self-corrections" were often repeated, but did not lead to overall improvement over time, as would have been expected if children had learned higher-order matching.

One child, Gwen, showed improvements across trials for most of her gestures. Unlike the other children's small variations in responding, Gwen's improvements were substantial and resulted in correct responding, which—once achieved—was reliably evoked by modelling in all of her remaining trials. Such gradual improvements were recorded for the unimanual "hand circle" gesture, the bimanual "tiger" gesture, the bimanual "bird facing" gesture, the bimanual "nose points" gesture, and the bimanual "horns" gesture. Gwen often alternated glances to her own hand configurations and those of the experimenter, as if comparing the two. For some gestures to which correct responses developed over time, Gwen held her hand configurations, once achieved, long after modelling.
stopped, as if reinforced by doing so. Unlike the remaining children, she seldom emitted correct responses and then reverted to incorrect responding in the later trials (although mixtures of correct and incorrect responses were emitted to some of hand-to-body touches; the incorrect responses were all inappropriate productions of well-established matching relations similar to those that were modelled).

Although it is not possible to directly compare children's matching repertoires in the present study—because different gestures were presented to different children over unequal numbers of trials—it appeared that Gwen responded correctly more often, more consistently, and to a larger proportion of target gestures presented to her, than did the remaining children: she correctly matched 32 out of 41 of her target gestures (78%). Across the remaining nine gestures she responded consistently, mostly with good approximations; thus "crossed arms" evoked small hug-like hand overlaps on her belly, the two "nose wiggle" gestures evoked hand movements that were in front or to side and often close to her face; "finger horns" evoked spread fingers at which she looked; "fist on temple" models evoked fist touches to cheek; and the two contralateral "shoulder touches" evoked ipsilateral shoulder touches. Modelling of "crossed hand wiggle" target gestures evoked responses that were not correct but appeared to be so when seen from Gwen's perspective—this configuration was reported to have been emitted by much older children in an earlier study (Baer & Deguchi, 1985). Unimanual "thumb up" models consistently evoked complementary (non-matching) responses of pointing and giggling.

Gwen's responding was consistent with multiple sources of control; it
appears that she emitted well-established trained responses to those models that evoked them reliably, perhaps across the majority of target gestures; most of these trained responses were correct matches. For the remaining gestures, her responding developed in a way suggestive of higher-order matching ability. However, although some of Gwen's data are consistent with higher-order matching, the present experiment was not designed to conclusively test children's higher-order matching abilities. Such a test would require knowledge of gestures that were never directly trained as matches, outside or within the experimental context, for all individual participants. Chapters 9 and 10 report on two studies that aimed to achieve just this.

To summarise. Children's matching of large arm movements, small hand movements, and hand-to-body touches, was consistent with generalisation of trained matching, although matching-through-naming could not be ruled out for all gestures and all children. Higher-order matching was a possible determinant of only one child's matching, across a small proportion of her target gestures.

Generalisation of trained matching may remain an important determinant of matching long into childhood. The next chapter presents an experiment that was designed to establish whether this is true for children aged up to 42 months.