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Is Newborn Imitation Developmentally Homologous to Later Social-Cognitive Skills?

ABSTRACT: *To assess claims about developmental homologies, or devologies, longitudinal data are needed. Here, we illustrate this with the debate about the purported foundational role of neonatal imitation in children's social and cognitive development. Cross-sectional studies over the past 35 years have clarified neither the prevalence of imitation in newborns nor its relationships to later developing skills. Thus, scholars have been able to maintain diametrically opposing explanations of neonatal imitation in the literature. Here, we discuss this issue and outline how large-scale longitudinal approaches promise to resolve such debates and have the potential to use individual difference measures to uncover links to later development.* © 2012 Wiley Periodicals, Inc. Dev Psychobiol 55: 52–58, 2013.

Keywords: *infant; developmental homology; imitation*

INTRODUCTION

Psychological traits may appear similar to one another for several reasons, one of which is common developmental descent. This may be akin to traits that are homologous between species, such as the forelimbs in crocodiles, koalas, and cats, which derived from the same ancestral body plan. Several quite distinct, even dissimilar, traits may also be linked through common developmental roots, just as the superficially very different forelimbs of whales, kangaroos, and bats are based on homologous bones. The concept of developmental homology, or what we suggest might be called devology, which is explored in this special issue may be a useful conceptual tool for developmental psychology. Indeed, understanding which traits derive from which earlier traits would seem essential for a full account of development. Knowing about these relationships is not only important for our theories, but could also point to significant clinical opportunities as early interventions should target those traits that are known to contribute to the development of later, clinically relevant traits.

A famous example of an early capacity that is purported to develop into a variety of similar as well as dissimilar later traits is neonatal imitation. It has been argued that a range of broad imitative skills and many distinct other developments in social cognition are based on a foundational capacity for imitation in newborns (Lepage & Theoret, 2007; Trevarthen & Aitken, 2001). Here, we discuss this case to illustrate how one might empirically examine such claims. We will argue for the need to gather comprehensive longitudinal data. Indeed, we propose that because of the current absence of such data, radically opposing interpretations have been maintained in the literature without resolution. Indeed, after 35 years of experimentation and debate on neonatal imitation, no consensus has been reached.

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Piaget (1962) proposed that one of the key achievements of the sensori-motor period (from birth to around 2 years) is the unfolding of a suite of imitative behaviors. He suggested that the important capacity for replicating the behaviors of others progressed through a series of stages, beginning with the repetition of already attained actions, through the replication of new actions on visible parts of the infant's own body, to the imitation of facial movements. Piaget believed that facial imitation emerged comparatively late as infants could not match the felt but unseen features of their own face, to the seen but unfelt features of another's face, until they had received adequate mirror exposure or sufficient tactual experience touching the faces of their mothers and comparing it with tactual exploration of their own faces. He thus maintained that a capacity for facial imitation did not emerge until around 12 months of age.

This view was challenged when Meltzoff and Moore (1977) first reported facial imitation in newborns. Rather than imitation emerging during the later phases of sensori-motor development, infants could apparently copy gestures immediately following birth. They appeared to be able to match what they see with what they do, without prior mirror or tactile matching experience. Meltzoff and Moore subsequently concluded that neonates are born with a capacity for active intermodal mapping (e.g., Meltzoff & Moore, 1994). They proposed that this "like-me" mechanism allows infants to engage in social interaction from birth and is the foundation not only of later forms of imitation but of various distinct later developments in social learning and cognition, such as empathy and theory of mind (e.g., Meltzoff, 2005). The idea is that when the "like-me" mechanism is paired with the first person experience that certain acts are associated with specific internal mental states (e.g., smiling and being happy) this opens the opportunity to infer the experiences of others. "Like-me" projections enable children to link observed acts in others (e.g., smile) with the mental states that the other is likely to be experiencing. Neonatal imitation is argued to be a basis, or devologue, of theory of mind.

In spite of the intuitive appeal of such proposals, alternative interpretations are possible. For instance, rather than neonatal imitation being the basis for more advanced cognitive functions, Bjorklund (1987) argued that it may be a specific adaptation to establish early social bonding, but then fades when other means of social interaction emerge. So the question of whether neonatal imitation is or is not the foundation of later social cognition has been a topic of focus for some time.

MIRROR NEURONS AND NEONATAL IMITATION

The proposal that neonatal imitation is crucial to diverse later developing skills gained support and attention in the wake of the discovery of mirror neurons in the premotor cortex of macaques (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Mirror neurons fire when the monkey performs a goal-directed action (such as grasping an object) as well as when it observes the same action performed by another. These neurological links between specific actions and their perceptions has caused great excitement and theories have since implicated mirror neurons in understanding of intention (e.g., Iacoboni et al., 2005), in language (e.g., D'Ausilio et al., 2009), empathy (e.g., Leslie, Johnson-Frey, & Grafton, 2004), theory of mind (e.g., Meltzoff & Decety, 2003), and imitation (e.g., Iacoboni, 2005). It has been argued that early dysfunction of the mirror neuron system might lead to imitation problems and a cascade of subsequent difficulties that are typical of autism (Williams, Whiten, Suddendorf, & Perrett, 2001). Mirror neurons thus provide a neurological explanation as to why neonatal imitation might be devologous to diverse later social-cognitive skills.

Indeed it has been proposed that neonatal imitation represents the first sign of a functional human mirror neuron system (Lepage & Theoret, 2007; Meltzoff & Decety, 2003; Nagy & Molnar, 2004). As imitation in newborns already involves cross-modal matching of equivalent visual and motor information, the mirror-neuron system appears to be operational at birth. Given the range of capacities that mirror neurons are purported to be crucially involved in, this theoretical link is consistent with the idea that neonatal imitation is a fundamental building block of human social cognition. Incidentally, there is now some evidence for neonatal imitation in rhesus monkeys (Ferrari, Paukner, Ionica, & Suomi, 2009), the primates in which mirror neurons were first discovered.

However, although these proposals may be plausible and appealing, there are important problems with the empirical bases of the major arguments. First, we only have limited evidence that mirror neurons even exist in humans, let alone play the fundamental roles ascribed to them. Only single cell recordings in monkeys have produced unequivocal evidence for mirror neurons. In these studies, mirror neurons fire in response to visual and motor events, but this does not necessarily mean that the neurons can transform a perceived input into the equivalent motor output (e.g., Jones, 2005). Second, mirror-neurons fire in response to goal-directed action such as reaching (Rizzolatti & Craighero, 2004) whereas neonatal imitation does not involve such goals (e.g., responses to mouth opening, lip pursing, or tongue protrusion). Third, mirror neurons were recorded in the neocortex, but neonatal imitation may be governed subcortically. Patients with severely impaired cortical function and little voluntary movement have been shown to display mouth opening imitation and reflexes typically found in newborns (Go & Konishi, 2008). In sum, in spite of the excitement, the discovery of mirror neurons has not necessarily strengthened the case that neonatal imitation is devologous to later social-cognitive traits. We therefore need to consider the behavioral data more carefully to examine this claim.

STUDIES ON NEONATAL IMITATION

Meltzoff and Moore (1977) originally presented 18 newborns with a modelled gesture (mouth opening, tongue protrusion, lip protrusion, and sequential finger movement) and found that they produced significantly more matching responses to the modelled gesture than when viewing the non-matching gestures. Since then dozens of studies have tested newborns with a myriad of model gestures such as emotional expressions, index finger protrusion, chin tapping, ear touching, waving, blinking, and so on. Though the vast majority of studies have been conducted in North America and Europe, there are also some studies that demonstrate neonatal imitation in other cultures. For example, 30-min-old babies of Maithil parentage, a people of northern Bihar, India, and eastern Tarai, Nepal have been reported to imitate (Reissland, 1988). Yet, in spite of the breadth of research on neonatal imitation, no study has produced direct evidence linking neonatal imitation to later social cognition. Indeed, some researchers even question the very existence of neonatal imitation, arguing instead that general arousal is responsible for what appear to be imitative responses (Hayes & Watson, 1981; Jones, 1996, 2006). Jones (1996, 2006), for example, argues that neonates in general tend to respond to visually interesting stimuli with tongue protrusions. If neonates find adult tongue protrusion interesting, infant and adult tongue protrusion may occur together without one imitating the other. Clearly, this radically sceptical view cannot explain why infants would flexibly match a broad range of gestures. However, in spite of the multitude of studies, this essential claim that infants copy a range of gestures has remained contentious.

In his meta-analyses, Anisfeld (1991, 1996) only found the evidence for matching of tongue protrusion compelling. He concluded that tongue protrusion imitation is a specific, directly elicited response akin to a newborn reflex (Abravanel & Sigafoos, 1984; Anisfeld, 1996; Jacobson, 1979; Kaitz, Meschulach-Sarfaty, Auerbach, & Eidelman, 1988). The visual stimulus of a tongue poking out of a mouth triggers an involuntary, reflexive motor response just as other inborn reflexes can be elicited through specific tactile stimuli. In line with this perspective, cross-sectional studies of early imitation indicate that most infants fail to show any imitative responses by 3 months or so (e.g., Abravanel & Sigafoos, 1984). This developmental pattern is similar to that of other neonatal reflexes that are at that stage subsumed by maturation of the motor cortex, as the infant with increasing muscle tone and mass progresses from stereotyped and reflexive behavior to increasingly goal-directed, voluntary movement (Thelen, Fisher, & Ridley-Johnson, 2002). These ideas about links to other neonatal reflexes, however, require direct empirical investigation. Much of the interpretation of this, just as of Jones's (2006) view, rests on the conclusion that neonatal imitation is not evident in a variety of actions, and so not based on flexible mapping of various inputs and outputs, but is restricted to a single, specific act: tongue protrusion.

Meltzoff and Moore (1997) strongly disagree with this conclusion and report in their own review of the very same data that Anisfeld reviewed that there is ample evidence for imitation of a host of gestures. They argue that their original findings have not only been replicated but extended to include a wide range of gestures in 25 independent studies from 13 different laboratories. They therefore maintain that neonatal imitation is not a limited reflex, or an arousal response, but demonstrates an innate human capacity for active intermodal mapping. The debate between these camps has not been resolved in subsequent studies. In the most recent review, Ray and Heyes (2011) conclude that only three of all the actions tested—facial expressions of emotion, lateral head movement, and tongue protrusion—have produced more positive than negative results. However, even if one accepts these three cases, it does not necessarily follow that they are the result of a general intermodal mapping mechanism. It remains possible that distinct mechanisms are responsible for each case. For example, lateral head movements may co-occur because of infant attempts at visual tracking whereas social smiles may merely express infant happiness upon seeing a smiling adult. And, as authors like Jones (1996, 2006) and Anisfeld (1991, 1996)) have vociferously maintained, tongue protrusion may, after all, be produced through arousal or reflexive mechanisms.

So in spite of extensive research efforts over the last 35 years, the field is deeply divided. There are several reasons for this state of affairs. For example, different studies have employed a variety of different coding schemes and it is neither a priori obvious nor widely agreed which one is the most appropriate. Scores may be calculated relative to different control conditions. After all, the actions are within neonates' repertoire and so can occur spontaneously or in response to stimuli other than the model of interest. The testing procedures themselves can differ in terms of length and repetitions of modeling and newborns are of course often not alert and attending. Different testing sessions may thus produce different results. Longitudinal approaches would be best suited to document the nature and prevalence of the imitative responses of infants over development. Yet, there is a surprising lack of truly developmental data in the literature.

THE LONGITUDINAL APPROACH

Very few studies of neonatal imitation have included longitudinal testing into later infancy, and these studies have all been relatively small in scale. In one study Maratos (1982), tested 12 infants at 1 month of age for imitation of mouth and head gestures and vocalizations, re-testing monthly until the infants were 6 months old. As a group, the infants reliably imitated mouth and head gestures in the first few months of life, but that skill declined around 3 months of age. This pattern is consistent with data from cross-sectional studies (Abravanel & Sigafoos, 1984; Fontaine, 1984). However, this study has been criticized for lack of methodological controls (see Anisfeld, 1991) and is limited in the conclusions that can be drawn about neonatal imitation because the infants were already 1 month old when first tested.

Kugiumutzakis (1999) longitudinally studied 14 infants beginning just after birth and following them until age 6 months. Infants were tested every 2 weeks for imitation of mouth and eye gestures and vocal sounds. Frequency of imitative responses, analyzed at the group level, indicated distinct longitudinal trajectories according to what was modelled. Imitation of mouth gestures declined from the newborn period to 3 months, but then reappeared by 6 months. Imitation of eye movements showed a steady decline from birth, and imitation of vocalizations emerged only around 2 months and then declined at 5 months. Based on these findings, Kugiumutzakis proposed that a generalized capacity to imitate is stable in the first 6 months of life, but that its expression in different gestures is dependent upon additional factors such as motivation and sensori-motor development.

Finally, Heimann, Nelson, and Schaller (1989) conducted a study that included 32 infants tested for imitation of mouth opening, tongue, and lip protrusion at 3 days, 3 weeks, and 3 months. This is the only longitudinal study to date that analyzed data at the level of the individual, focusing on intra-infant consistency and stability of imitative responses across testing sessions. Infants were assigned imitation scores based on the relative frequencies with which they produced the target behaviors. This study found significant correlations between infants' imitative tongue protrusions across the first two testing sessions, but by the third test session at 3 months, levels of imitation had generally faded so no correlations with earlier behavior were evident. In a later analysis, Heimann (1998) categorized each infant at each testing session as being generally high or low on imitation, and found that the high and low imitators at 3 days tended to fall into the same category at 3 months, supporting the conclusion that imitative behavior was consistent from 3 days up to age 3 months. Unfortunately, no statistical analyses were reported for this finding. This re-coding also highlights that in the neonatal imitation literature variations in coding and scoring can have substantial effects on the conclusions drawn (see also Heimann et al., 1989).

Heimann (1989) also evaluated elements of social behavior during mother–infant interaction at 3 months of age and found significant negative correlations between imitation (during all three testing sessions) and infants' tendencies to look away from their mothers' faces during the interaction. The more imitative infants maintained steadier eye contact during face-to-face interaction with their mothers than the other infants. This is the only empirical evidence to date supporting the idea that neonatal imitation is linked to other social behaviors. It is a promising start, but requires replication, especially given the relatively small sample size (of the 32 infants in Heimann's sample, only 16 contributed data at all three testing sessions).

In an additional follow-up, Heimann (1998) tested 30 of the infants at 12 months of age on 16 different imitation tasks including bodily gestures, object-directed actions, and vocalizations. No associations were found between neonatal imitation at 3 days and imitation at 12 months, nor were there associations between imitation at 3 weeks and at 12 months. However, two significant correlations emerged between the 3-month and 12-month testing sessions: imitation of tongue protrusion at 3 months was correlated with vocal imitation at 12 months ($r = .42$), and imitation of mouth opening at 3 months was correlated with object-directed imitation at 12 months ($r = .38$). However, these results should be treated with caution as Heimann did not report any adjustment for family-wise error rate. Using a Bonferronni adjustment for 16 separate correlations, neither of these two correlations remains statistically significant. Therefore, these data offer scant support for the idea that neonatal imitation is develogous with later imitation. Heimann (1998) also assessed the 12-month-olds on spontaneous imitation in free play, vocabulary development and temperament. None of these social traits were correlated with early imitation. However, given the limited statistical power of this study, it remains quite possible that neonatal imitation is linked to later imitation and other social-cognitive skills.

The nature of neonatal imitation, its prevalence, time course, and role in subsequent development has remained controversial. We believe that only systematic longitudinal study can promise resolutions. What is the actual range of gestures newborns are capable of imitating and how consistent are imitative responses, within and between testing sessions? What is the developmental pathway of these responses, for instance in relation to various neonatal reflexes? How prevalent are imitative responses in the newborn population and can individual differences be informative? If neonatal imitation is a deliberate social act, then infants with a more social temperament could be expected to display more imitation than others. If neonatal imitation is the basis of later imitation, if these phenomena are devologous, then infants who show more neonatal imitation would be expected to also score higher on later imitation tasks. Large-scale longitudinal studies with sufficient power to exploit individual differences are essential to substantiate claims that neonatal imitation is a foundation of diverse later social-cognitive traits.

We are currently conducting a longitudinal study to establish the nature of neonatal imitation and its role in cognitive development. We aim to test up to 100 infants in the first week after birth and at regular intervals up to 18 months of age. At each test infants are presented with models of facial, manual, and vocal gestures. We also assess the development of reflexes and a range of other variables at various stages, such as motor development, temperament, social cognition, language, and imitation. We believe that non-partisan, large-scale, longitudinal projects can resolve vexing developmental questions and are essential to evaluating potential developmental homologies.

Though we are enthusiastic about their potential, such longitudinal designs do, of course, have their well-known drawbacks. Such studies are time-consuming and resource intensive. The dedicated repeated testing of infants requires prolonged commitment from both participants and researchers. Dropouts and missing values are serious practical problems that can undermine the power of the design. The approach assumes that reliable individual differences can be captured and are persistent across the relevant stages of development. It is, however, possible that a trait is devologous to a later trait and yet there are no discernable associations based on competence or time of emergence in a longitudinal investigation because different factors may drive individual differences at different stages of testing. Even when there are correlations linking traits across development, these may be driven by third variables, such as differences in temperament, rather than by the purported developmental relation between the traits. Finally, repeated testing, as always, can bring with it unwanted carry-over effects. The longitudinal research itself may influence the data.

In spite of these drawbacks, the longitudinal approach to examining potential devologues has key advantages. It is the only way to examine development directly and track changes in individuals. Many of the problems can be explicitly addressed. For instance, a longitudinal study can be complemented with carefully chosen cross-sectional studies to evaluate if there are any carry-over effects. If the cross-sectional data are significantly different from the longitudinal, then there is reason to suspect that repeated testing influenced results. Similarly, if correlational data support the idea of a developmental homology, then this can be followed up with intervention or training studies to substantiate such findings. If there were associations between neonatal imitation scores and later performances, one could, for instance, investigate whether infants trained in early imitation have higher scores on later imitation tasks and other social-cognitive outcomes than children who do not receive such early intervention. This could prove critical for interventions aimed at ameliorating some of the deficits or deficiencies associated with atypical development, such as in autism.

In spite of some shortcomings, we argue that longitudinal approaches, when paired with appropriate follow-ups, are best suited to examine potential developmental homologies. By examining the relationship between individual differences in early and later developing capacities, we can discover hidden links between quite distinct-looking traits as well as question whether behaviors that on the face of it appear to be similar, do in fact derive from a common origin. Large-scale longitudinal studies are resource intensive, but potential developmental homologies deserve careful empirical investigation. Their identification could have profound theoretical and applied benefits.

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