

14 Parent-Offspring Conflict and the Development of Social Understanding

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Human infants exhibit a number of behaviors that have been interpreted as evidence of an early ability to represent and reason about mental states (theory of mind). We reconsider these behaviors in light of evolutionary theory concerning parent-offspring conflict. We speculate that some of them, which intuitively appear to provide evidence of an ability to reason about the mental states of others, might in fact reflect a history of selection for behaviors that only appear to be generated by such an ability. We hypothesize that certain infant behaviors might have been evolved in order to extract higher levels of parental and caretaker investment. All other things being equal, parents will invest more when the perceived quality of the infant is higher. In this case, we suggest that parents would have invested more in infants who exhibited behaviors similar to their own, especially when the behaviors caused adults to attribute a higher degree of infant social understanding.

In what follows, we briefly review the theory of parent-offspring conflict and consider the role of this conflict in the cognitive development of human infants. Next, we discuss the evolution of theory of mind – which we take to have its origins in human evolution – and consider how this human cognitive specialization might have interacted with existing parent-offspring dynamics. We show how the epigenetic systems of infants might have responded by elaborating upon existing cognitive and behavioral systems, or by canalizing later-developing ones earlier into development, in order to recruit higher degrees of parental investment. We assess the merits of our framework in the context of the development of behaviors considered by some researchers to be indicative of a certain degree of social understanding, namely gaze-following, pointing, social smiling, and neonatal imitation. We conclude by showing how this proposal makes several long-standing theoretical and methodological difficulties for the field of cognitive development even more vexing.

1 Parental Investment and Parent-Offspring Conflict

The theoretical underpinnings of parental investment strategies were first worked out by Trivers (1974), who realized that the different genetic interests of parents and their offspring can account for behavioral conflicts between the two. From Hamilton's (1964) landmark work on inclusive fitness, Trivers (1974) was able to derive the following asymmetry of interest:

At any moment in the period of [parental investment] the female is selected to invest that amount [in her infant] which maximizes the difference between the associated cost and benefit... The infant is selected to induce that investment which maximizes the difference between the benefit and cost devalued by the relevant [degree of relatedness] (p. 252).

Because social mammals typically reproduce more than once, and because they typically invest a substantial amount of resources in caring for their young after birth, parents must seek some way of limiting investment in any given infant. Simply put, too much energy investment in a current infant might be at the expense of the production and care of future or related infants (or kin). Trivers showed that the optimal amount of investment in a current infant can be understood as a mathematical function which maximizes the chance that the infant will survive to the point at which it can reproduce, but minimizes costs to potential future infants (or closely related kin). In contrast to parental efforts in minimizing investment, the infant should favor increases in parental investment. Examples of the conflicts that emerge from the partial asymmetry of interests between infant and parents are widespread (for a classic study with non-human primates, see Altmann, 1980). Presumably, weaning conflict has evolved precisely because of the differential interests of the mother and the infants. Maestripieri (2002) has recently reviewed the literature in this area and argues that parent-offspring conflict remains an important and valuable explanatory framework in primate biology.

In humans, evidence of parent-offspring conflict can be seen even before birth. First, up to half of all pregnancies end in spontaneous abortions, abortions which might be due to the mother's physiological evaluation of the fetus (Gaulin & McBurney, 2001). Second, the normal physiological relationships between the fetus

and mother might reflect such conflict. Haig (1993), for example, considered mother-fetus conflicts in which the fetus attempts to manipulate maternal physiology for its own benefit, and the maternal physiology responds to counteract these manipulations. Examples of fetal manipulations include actions that reduce the probability of miscarriage, actions that increase nutrient supply in maternal blood, and actions that increase the duration of pregnancy. Each of these manipulations, while providing direct benefits to the fetus, can be problematic for the mother. When the fetus is of low fitness value, reducing the probability of a miscarriage is advantageous only to the fetus. Increased nutrient supply in maternal blood also benefits the fetus, but extreme variations of blood sugar (for example) might produce gestational diabetes in the mother. Additionally, increases in the duration of pregnancy, while providing more resources to the fetus, can be dangerous to the mother due to increased size of the infant at term. Thus, even before birth, infants might engage in a parental conflict over investment (in this case, with their mother).

2 Infant Cognitive Development in Light of Parent-offspring Conflict

Trivers (1974) anticipated the application of parent-offspring conflict for understanding the evolution and ontogeny of infant cognitive skills. In describing the infant as a "psychological manipulator" (p. 257), Trivers noted that the asymmetry in physical size between the parents and infants has selected infants to deploy psychological tactics in order to induce parents to provide higher levels of investment than they have been selected to give. He noted that once a system of "honest" communication has evolved between the infant and its mother about the infant's immediate needs,

...the infant can begin to employ it out of context. The offspring can cry not only when it is famished but also when it merely wants more food than the parent is selected to give. Likewise, it can begin to withhold its smile until it has gotten its way. Selection will then of course favor parental ability to discriminate the two uses of the signals, but still subtler mimicry and deception are always possible (p. 257).

It is important for our purposes here to note that Trivers used this logic to explain parent-offspring conflict that is widespread among species that provide investment in their offspring after birth.

Two additional points should be made in relation to Trivers' observations. First, the domains of parent-offspring conflict within a species would presumably become fairly well-defined over time. That is, there would be some circumscribed arenas in which the evolutionary dance of the appearance of new infant behavioral strategies, followed by the emergence of adult counter-strategies, would continue. Within these arenas, there would be a continual tweaking of such strategies, but the basic arenas in which this evolutionary cycle would go on should be relatively fixed until some further changes were introduced into the behavioral repertoire of the species (for other reasons) – modifications that enabled infant, parent, or both to exploit this new behavioral arena. To anticipate, we suggest below that the emergence of theory of mind in the course of human evolution was one such a modification.

Another point in relation to Trivers' (1974) argument should be made. At least two different means of parental exploitation are available. Trivers emphasized that infants would exploit parental resources by behaving in a manner less mature, and thus in need of more resources, than their chronological age would suggest. For example, a child might use a strategy of crying to obtain more food or attention. As a young infant is "more helpless and vulnerable ... its parents will have been more strongly selected to respond positively to signals of need emitted by the offspring, the younger that offspring is" (Trivers, 1974, p. 257) or appears to be. Of course, it is also highly likely that age-related changes in crying might have been selected for in order to maximize investment. However, there are clearly limits on the use of such a strategy, even at ages in which some crying might be beneficial. Experimental research has shown that exposure to the sight and sound of crying increases various indicators of stress-induced arousal in adult observers, and can increase frustration and aggression (Donovan & Leavitt, 1985; Donovan, Leavitt, & Balling, 1978; Murray, 1985; Frodi & Lamb, 1980). Thus, although some degree of crying is likely to extract a higher degree of parental investment, extreme crying might also place infants at risk. For example, crying is the most widely cited cause of "shaken baby syndrome" (Becker, Liersch, Tautz, Schlueter, & Andler, 1998; Dykes, 1986) and might be the "primary reason for aggression" directed at children under two years of age (see Norman, 1983).

Another means by which infants can exploit additional resources is through social behaviors that generate positive regard and affect from caregivers. For example, parents might delight in the imitations of their new infant (Meltzoff & Moore, 1977), in the social smiling of their two-month-old (Wolff, 1963), or in the speech-like vocalizations of their three-month-olds (Beaumont & Bloom, 1993). Such behaviors might lead to parental attribution of a high level of social understanding to the infant and, in combination with other factors (e.g., breast feeding; see review in DiGirolamo, Grummer-Strawn, & Fein, 2001), increase the degree of attachment between caregiver and infant (Klaus, Kennell, & Klaus, 1995). By producing behaviors that lead to positive regard and affect, and increasing the attachment between caregiver and infant, the infant's behaviors can reduce the very real possibilities of suffering neglect, abuse, or abandonment (Klaus & Kennel, 2001; Sameroff & Chandler, 1975), and thus these strategies for recruiting resources have quite different limits than those faced by immaturity-based strategies. Indeed, the emotional regard and attachment generated by these behaviors might constitute a core basis for caregivers providing additional resources. With the initial onset of theory of mind in early humans (see next section of this paper), the potential for more complex relationships started. Infants now could generate behaviors tapping into this increased social understanding and form attachment bonds that could increase their chance of surviving to maturity given this new psychological environment. This strategy for recruiting resources might be successful in large part because of the lack of overt conflict. By bonding with the parent, the child makes it more difficult for the parent to give him or her fewer resources.

3 Evolution of Theory of Mind in Humans: New Strategic Fodder for Infants

In what follows, we outline our hypothesis that the evolution of the human capacity for reasoning about mental states (theory of mind) opened up a new arena in the ongoing parent-offspring conflict. The evolutionary emergence of theory of mind might have provided infants with a new avenue for recruiting additional parental investment. Once parents began to respond to the psychological states of their infants, in addition to their overt behavioral states, infants could begin to evolve behaviors that would, in effect, manipulate this ability for their own benefit.

We assume (based on our assessment of the current evidence) that the capacity to reason about mental states evolved sometime after the separation of humans from other hominoids (see Povinelli & Bering, 2002), but it is important to note that our hypothesis does not depend upon this inference. Even if the time-frame we advocate turns out to be incorrect (that is, if theory of mind abilities are more widespread than we believe), this would only mean that humans exhibit simply an example of a more widespread phenomenon. Nonetheless, it is important to make some assumption about the timing of the evolution of theory of mind in order to explain how it was integrated into earlier psychological systems. We recognize that this claim is controversial and so we direct our readers' attention to other authors who believe the evidence supports a wider distribution of this ability in living primates or other taxa (e.g., Hare, Call, Agnetta, & Tomasello, 2000; Hare et al., 2000; Boesch & Boesch-Achermann, 2000; Call & Tomasello, 2003; Suddendorf & Whiten, 2001).

Our current conclusion that theory of mind is restricted to our species does not imply that only humans exhibit complex social behaviors; indeed, many social species produce behaviors which, on the surface, resemble behaviors often associated in our species with the functioning of theory of mind. Certain complex social behaviors seem especially elaborated in primates, especially in chimpanzees (e.g., deception, gaze-following, reconciliation and 'holding grudges' after fights: Whiten & Byrne, 1988; Goodall, 1986; de Waal, 1982, 1986, 1989; Povinelli & Eddy, 1996a; Tomasello, Call, & Hare, 1998).

Some scholars will wonder how chimpanzees and other non-human animals could lack an understanding of mental states when they share with us so many of the behaviors which, in humans, we would interpret as prima facie evidence of the ability to represent mental states. We have offered one possible solution to this apparent problem: namely, that the connection between our representation of each other's mental states and our overt behavior is far more complex than introspection suggests (e.g., Povinelli & Giambrone, 1999, 2000; Povinelli & Prince, 1998). In short, many behaviors which our folk psychology tells us are being generated by inferences about what others are thinking or feeling, might in fact have multiple causes, and furthermore, many of these behaviors might have originally been supported by psychological systems unrelated to theory of mind. Gaze-following is an excellent case in point. Although we are certainly capable of attending to and following the gaze of others as a consequence of wondering what it is that they see, it is not at all

clear that this is always or even usually the proximate cause of gaze-following in adult humans. Recent research hints at the operation of precisely such a dual system of responding to gaze in humans adults (e.g., Driver, Davis, Ricciardelli, Kidd, Maxwell, & Baron-Cohen, 1999; Kingstone, Friesen, & Gazzaniga, 2000; Langton & Bruce, 1999). The general point is that systems which enable reasoning about the behavior of others and its relationship to other observable events might often suffice.

Based on the above line of thinking, we have argued that the ability to reason about mental states evolved as a unique specialization of the human species, and its initial function was to understand ancient, already-existing behaviors in a novel way (a mentalistic way), and therefore more flexibly deploy them – not to endow us with a multitude of fundamentally new behaviors (for detailed descriptions of this hypothesis, see Povinelli & Giambrone, 1999, 2000; Povinelli & Prince, 1998). In short, the initial selective advantage of theory of mind was for greater flexibility in combining and recombining old behavioral patterns. The psychological system for representing the mental states of others might therefore reside alongside (and interact in complicated ways with) more ancient systems for keeping track of and reasoning about the behavior of others. The significance of this framework is that it leads one to expect, a priori, that chimpanzees and humans would share numerous, nearly identical behavioral patterns, and yet understand them differently (with chimpanzees reasoning strictly about the behavioral propensities of others, and humans reasoning about both behavioral propensities and mental states). In our view, this is what the experimental data suggest. Because this interpretation holds that humans evolved a cognitive specialization that allowed our species to interpret existing behaviors in new ways, we have referred to it as the ‘reinterpretation’ hypothesis (Povinelli & Giambrone, 1999, 2000).

The reinterpretation hypothesis has two important implications for the model that we are proposing. First, it suggests a particular evolutionary time-point for the emergence of a new arena for parent-offspring conflict in ancestral hominoids: the evolutionary appearance of theory of mind. If theory of mind is a novel (or even largely novel) specialization of the human lineage, then this addition to the parent-offspring conflict occurred sometime after the split of humans and chimpanzees. Second, just as chimpanzees might engage in behaviors like deception without appreciating how they connect to the underlying mental states of others, so too might human infants. For example, when a 2-month-old infant smiles in response to her

mother gazing at her, this smile might not be driven by sophisticated social recognition or knowledge of the mother's emotional or mental states. Rather, as we shall see, it might be the result of a finely honed evolutionary strategy in which smiling yields more investment.

4 Parent-offspring Conflict and the Evolution of Behavioral 'Imposters'

We use the term 'imposter' to indicate a sub-class of behaviors exhibited by human infants that evolved to exploit the human adult's theory-of-mind system. When a parent attributes a high degree of social understanding to their infant, there are several possible psychological bases for the infant's behaviors. On the one hand, the infant's behaviors might indicate the presence of precisely the kind of social understanding attributed to him or her by the parent. At some point in development, most children will develop the ability to explicitly reason about mental states, because the child will develop the same social understanding that is modally present in human adults. Conversely, the parent's attribution could be incorrect. A given behavior exhibited by the infant, while appearing to result from an ability to reason about mental states, could instead be caused by other psychological systems. Because of their purported evolutionary history, we label these latter class of behaviors as 'imposters.' These proposed 'imposters' would be, of course, ontogenetic adaptations (Oppenheim, 1981), or transient processes enabling an infant to adapt to particular stages of development. Only when viewed through the lens of progression to more adult-like or mature states are these 'imposters' really imposters. Below, we propose three ways in which such 'imposters' could have originated through selection on infants to act like they possess a theory of mind, without necessarily having the ability to represent mental states. In each case, the evolution of the infants' behavior is being driven by the ability to extract additional levels of parental investment.

- (1) Neurological substrates for the behavior were present in the infants of the common ancestor of humans and the African apes; however, human infants evolved subtle alterations in these behaviors once a developmental pathway in humans was established for representing mental states and hence allowing adults to (incorrectly) construe these behaviors in terms of the infants ability to reason about mental states (for example, by shifting the behaviors earlier and earlier into development).

- (2) Specific neurological substrates for the behavior were not present in the infants of the common ancestor of humans and the African apes, but rather, the evolution of a theory of mind in adult humans led to the evolution of some entirely novel behaviors in infancy.
- (3) Finally, the neurological substrates were present in the infants of the common ancestor of humans and African apes, but they subserved a different function. Once human adults began to evolve a theory of mind, some behaviors (e.g., smiling) could be interpreted very differently by human parents, and were therefore evolutionarily modified by infants to gain additional resources based on this new parental interpretation.

Below, we examine some infant behaviors which might be outcomes of the three processes isolated above.

4.1 Gaze-following

Certain aspects of gaze following in early infancy might have been shaped by the first process. Human infants, starting at 6 months or younger, develop an ability to follow the gaze of others (e.g., Scaife & Bruner, 1975; Butterworth & Jarrett, 1991; Corkum & Moore, 1998; D'Entremont, Hains, & Muir, 1997). Infants of this age will follow an adult's gaze within their own visual field, and orient to the first object along their scan path from the adult's face. After 12-months, infants' gaze following is said to progress to a "geometric" mechanism which enables localization of the specific target of an adult's gaze – provided the object is within the infant's visual field (e.g., Butterworth & Jarrett, 1991). Similar gaze-following abilities are present in chimpanzees and other Old and New World anthropoid primates, but possibly not prosimians (Anderson & Mitchell, 1999; Emery, Lorincz, Perrett, Oram, & Baker, 1997; Itukura, 1996; Povinelli & Eddy, 1996a, b; 1997; Tomasello, Call, & Hare, 1998; Tomasello, Hare, & Fogleman, 2001).

Given its phyletic distribution among living primates, we can be very confident that at least major components of a gaze-following system were present in the common ancestor of humans and apes. However, we hypothesize that once a theory-of-mind system evolved and was firmly established in the development of modern humans, human infants began to take advantage of the new, mentalistic construal of gaze direction now present in older children and/or adults. Infants might

have shifted aspects of the gaze-following system earlier and earlier in development. Further, and consistent with both the first and third mechanism identified above, infants might have also evolved subtle alterations in their behaviors related to gaze following. For example, they might have begun to yoke affective expressions with gaze alternations from the parent to other objects of interest, leading to parental attributions of higher levels of social awareness. In this case, infants would have preserved the general function of their behavior, but tweaked it to maximize resource investment. Because gaze-following is present in many social primate species, and therefore must have a shared ontogenetic trajectory, its form in human infancy is an imposter only to the extent that selection might have shaped its specific expression precisely so that it would more readily trigger the adult theory-of-mind system. Of course, at some point in human development (and the exact age is still a matter of empirical controversy), infants do begin to construe gaze in a mentalistic fashion.

4.2 *Indexical Pointing*

Pointing in infancy might be an example of a behavior that arose through the second process. Younger than 3 months, infant humans spontaneously display early forms of ‘pointing’ by extending their index fingers from their otherwise closed fist (Hannan & Fogel, 1987). However, even by 5 months, the index finger extensions of human infants is not coordinated with their gaze direction towards adults or objects in the world (Hannan & Fogel, 1987). In contrast, by 12 months pointing involves extension of the arm, use of the index finger, and gaze coordination with another person (e.g., Franco & Butterworth, 1996), with infants looking in the general direction of another’s pointing gesture (e.g., Morissette, Ricard, & Décarie, 1995). By about 15 months of age, infants are able to precisely localize the intended targets of the pointing gestures of others (Morissette et al., 1995; Lempers, 1979). Pointing by young infants might be well characterized as “proto-imperative” (Bates, Camaioni, & Volterra, 1975), involving an infant instrumentally using a parent (see also Mosier & Rogoff, 1994). Although chimpanzees raised with humans do develop whole arm, hand, and even index finger extensions towards objects that they want when interacting with humans (review by Leavens & Hopkins, 1999), they do not use such gestures with each other, and there is substantial reason to suppose that they do not understand that the gesture connects to the mental states of others (review Povinelli, Bering, & Giambrone, in press). Indeed, the conspicuous absence of pointing in free-

ranging chimpanzees (e.g., Plooi, 1978), is perhaps best highlighted by the ambiguity of the single published instance of a possible example of pointing by chimpanzees in the 40 years this species has been intensively studied in its natural habitats (Vea & Sabater-Pi, 1998). (Interestingly, specialization of the action of the tendons of the index finger that might be relevant to the topographical form of the gesture have been noted in humans as compared to chimpanzees; see Povinelli & Davis, 1994).

We interpret the lack of pointing behavior in chimpanzees and other great apes to indicate that the behavior of pointing was not present in the common ancestor of humans and the great apes. Rather, it appears to have evolved exclusively in the human lineage. We propose that pointing in young human infants evolved after adult humans had evolved the capacity to reason about mental states and had begun to incorporate the pointing gesture into their behavior. Aspects of the topographic form of the gesture might have become canalized into infancy without any supporting relationship from an understanding of mental states. We suggest that it is not until late infancy (around 18-24 months) that pointing begins to develop into a gesture directly related to human infants' understanding of reference and communication (see Moore & D'Entremont, 2001) – both related to an understanding of mental states.

4.3 *Social Smiling*

Finally, early social smiling might be an example of a behavior that arose through the third process we described above. Social smiling emerges in young human infants at around 2 months of age. It is produced when the infant views the face and eyes of an observer, and also appears related to the contingency of the observer's behavior with the child's behavior. Young infants inspect a face presented to them, then focus on the eyes of the observer, and break out suddenly "into a broad smile or grin" and "this sequence of events [can] be repeated many times" (Wolff, 1963, pp. 122-123). Prior to 4 to 6 weeks, infants will smile to some external stimuli (e.g., light touches) and also to some internal stimuli (e.g. during REM sleep) (Emde & Koenig, 1969). From four to six weeks through to approximately six months, the most effective stimuli for evoking smiling in the infant is a moving 'en face' approximate configuration of the face (Spitz & Wolf, 1946). Infants of this age vary their smiling based on stimulus features including eye-gaze (Symons, Hains, Muir, 1998; Hains & Muir, 1996a) and contingency (Hains & Muir, 1996b; Tronick, Als, Adamson, Wise, & Brazelton, 1978; Watson, 1972). Chimpanzees and other nonhuman primates display facial

gestures that resemble bare teeth smiles, but the social function of these gestures differs radically from the function of smiling in humans. Often, these facial displays indicate fear or submission (van Hooff, 1972).

We suggest that a specific behavioral substrate for smiling was present in the common ancestor of humans and other great apes, but once social smiling in adults began to have meanings such as appeasement, expression of empathy, acknowledgement, and attraction, infants began to utilize smiling as a facial gesture to ingratiate themselves in their parents' eyes.

4.4 *Other Candidate Behaviors*

Thus far, we have considered only a handful of behaviors that human infants might display in the absence of the mature, folk psychology that typically accompanies their production in older humans. Table 1 lists a number of additional behaviors that might be productively analyzed using the general framework outlined here. Thus, although some researchers have interpreted the behaviors listed in Table 1 as evidence that infants represent aspects of the mental states of others, it is possible that some of these behaviors might be supported by other kinds of representations – ones not specifically involved in reasoning about mental states per se. After all, if our general model is correct, the initial selective advantages that led to the sculpting of new social behaviors in infants (and/or the modification of existing ones) resulted from the fact that these behaviors elicited increased levels of parental investment, regardless of whether those behaviors reflect sophisticated social understanding or not.

5 Behavioral Imposters vs. Early Theory of Mind: A Comparison of Explanatory Frameworks

It is important to note that even if the proposal advanced here has merit, the new arenas of parent-offspring conflict that might have been opened up by the evolutionary emergence of theory of mind, could have led to selection pressures for earlier (if more fragile) manifestations of genuine social understanding related to theory of mind (as opposed to selection for imposters alone). For example, it might be the case that what was canalized was a general representational code linking self and other – as proposed, for example, by Meltzoff and Gopnik (1993; see also Gopnik & Meltzoff, 1997). According to these authors, the existence of neonatal imitation demonstrated by Meltzoff and colleagues (e.g., Meltzoff & Moore, 1977, 1994)

suggests that human infants begin life with a system of abstract cross-modal representation providing them with an experiential similarity in their representations of self and other. With this system, they are “launched on their career of interpersonal relations with the primary perceptual judgement ‘Here is something like me’” (Meltzoff & Gopnik, 1993, p. 336). This innate representational system is seen as laying the foundation for the child’s conception of the social world in terms of theory-like structures. Thus, although the initial developmental pathway for theory of mind might have been present in older individuals, through time, there might have been selection for these abilities to appear earlier and earlier in development. Alternatively, as we have proposed here, instead of dragging these later emerging representational systems toward earlier ontogenetic time points, selection might have acted to favor infants who expressed behaviors that structurally resembled behaviors interpretable by adults as expressing those abilities.

Meltzoff and Gopnik’s (1993) proposal suggests that there is substantial continuity or overlap between the mechanisms responsible for neonatal imitation and those that support adult imitation. This possibility can be evaluated from a neurobiological standpoint. Functional imaging studies have implicated several divisions of cortex in adult imitation; results vary somewhat across studies, but activation of inferior parietal area 40 and frontal opercular area 44 (also known as area F5 of ventral premotor cortex) are commonly noted (see, for example, Chaminade, Meltzoff, & Decety, 2002; Decety, Chaminade, Grezes, & Meltzoff, 2002; Goldenberg, 2001; Iacoboni, Woods, Brass, Bekkering, Mazziotta, & Rizzolatti, 1999; Nishitani & Hari, 2000). The involvement of the inferior parietal and frontal opercular areas in gestural imitation is consistent with reports that both areas represent orofacial and upper limb movements, and both areas are known to be responsive when subjects view or execute movements (Buccino, Binkofski, Fink, Fadiga, Fogassi, Gallese, Seitz, Zilles, Rizzolatti, & Freund, 2001). Nonhuman primates appear to possess parietal and frontal areas homologous to those that support imitation in humans (Johnson, 2002; Preuss, 1995; Rizzolatti & Arbib, 1998), and these areas contain matched motor and visual representations of movement. Cells with such coincident visual and motor properties have been dubbed “mirror neurons” (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). These areas are also strongly interconnected (review by Wise, Boussaoud, Johnson, & Caminiti, 1997). It is worth remembering, however, that the ability to intentionally copy observed movements is

quite limited in species other than humans, and therefore the parietal and frontal territories that support adult-like imitation must have been recently modified in human evolution.

If adult imitation depends critically on the cortical structures discussed above, then it is unlikely that neonatal and adult imitation share the same substrates, if only because human cortex is very immature at birth. This immaturity is manifest in many aspects of anatomy and physiological organization, including synaptic density, dendritic elaboration, myelination, electrical activity, and metabolic activity (Albert, Diamond, Fitch, Neville, Rapp, & Tallal, 1999). It is conceivable that the specific cortical structures and circuits involved in adult imitation follow an accelerated developmental schedule relative to neighboring areas, but there is no evidence of this. It seems more likely, on neurobiological grounds, that neonatal imitation is supported by different mechanisms than adult imitation, and specifically by subcortical systems, which are more mature at birth than cortical systems (Johnson, 1990). One structure that should be considered in this role is the superior colliculus (cf. Johnson, 1990). Although often treated by primate neuroscientists merely as an eye-movement center, it is substantially more than that: the colliculus contains spatially matched visual, auditory, and somatosensory maps, providing a basis for multimodal sensory integration (reviewed by Preuss, 2004). Moreover, in addition to eye movements, it organizes movements of the mouth, face, and forelimbs (Dean, Redgrave, & Westby, 1989; Werner, 1993). The superior colliculus receives projections from parietal and frontal cortex in nonhuman primates (Fries, 1984); assuming that similar connections are present in humans, these could provide the basis for the transition of the control of imitation to cortical systems as the latter mature. Of course, given that there is no solid evidence that nonhuman primates exhibit neonatal imitation, our suggestion that the colliculus is involved in human neonatal imitation implies that aspects of this structure were functionally modified during hominid evolution. Likewise, we must assume that the cortical structures involved in adult imitation were modified, as nonhuman primates are not specialized for the intentional copying of observed movements.

Whatever the exact mechanisms supporting neonatal imitation, our model posits a history of selection for neonates and infants that expressed behaviors superficially resembling later-developing behaviors (i.e., true imitation). In the context of facial imitation, such behaviors might have been especially important given

the relatively greater amount of face-to-face interactions in human development (as opposed to developmental patterns found in other primates) – a difference that might itself be a byproduct of the evolution of theory of mind during the course of human evolution. Thus, infants who reacted to adult facial expressions with gestures that were structurally matched and temporally coordinated, would be likely to receive higher levels of attribution of social awareness, and hence more and earlier investment. We emphasize that our behavioral imposters are not necessarily fixed-action-patterns (cogently argued against by Meltzoff and colleagues). Indeed, our model does not deny that neonatal imitation is a process of ‘active intermodal mapping’, and thus can account for the diversity of evidence gathered in this area (e.g., Meltzoff & Moore, 1997). Instead, it posits that this mapping principally involves subcortical systems, rather than the cerebral structures that seem to be involved in the kinds of imitation seen in older infants, children and adults. In contrast, whereas Meltzoff and Gopnik (1993) seem to posit a continuity of cortical functions from birth forward, our account posits a major role for multimodal, but subcortical representations at birth, which become integrated with cortical systems later in development. Thus, whereas both accounts acknowledge the common coding of visual and motor information at birth in humans, our model questions whether the mere expression of this common coding in overt behavior (through imitation) warrants the attribution of any kind of intentional understanding on the part of the infant (for a related account of neonatal imitation, also see Bjorklund, 1987). Interestingly, however, if our model is correct, the neonatal system for imitation might have been exquisitely designed to yield precisely such attributions by our naïve folk psychology.

At this point, one might argue that the sheer diversity of evidence for early social understanding in infants already constrains the possibilities for what the outcome of parent-offspring conflict must have been: early social understanding of intentional states (e.g., Johnson, 2000). Scholars sympathetic to such a view differ widely in their opinions about the nature of such early understanding. Some see the evidence as supporting the view that infants possess a genuine, but more circumscribed or different understanding of intentional states, while others see the knowledge as starkly domain-specific; still others characterize the infants’ understanding of intentional states as neither genuinely mentalistic nor strictly behavioral. Despite such diversity of opinion, these scholars could, in principle,

accept the general proposal we have made, but still conclude that the best evidence now suggests that the long-term outcome of this evolutionary arms race was to select for the increasingly earlier development of sophisticated social understanding. In other words, parent-offspring conflict might have favored infants who developed theory-of-mind-like abilities earlier in development. Some evidence which could be used to bolster this view is presented in Table 2. It should be noted that this evidence has been gathered in the context of efforts to explicitly test predictions concerning alternative ideas about the kinds of social understanding present in infancy.

However, it could be the case that despite such targeted analyses, researchers are actually uncovering the very areas in which infants were selected to detect and respond to the statistical regularities that exist in the actions of their caregivers. The detection and use of these regularities does not necessarily imply a system for understanding mental states, but it might provide the means by which they could maximally exploit their caregivers. That there are statistical regularities in the behavior of others is not particularly controversial; indeed, it can be shown that not only must such regularities exist, they must be detectable in many social species who use such information in their interactions with each other (see Povinelli, 2001), and in the case of human development, some researchers are now demonstrating precisely such abilities (Baird & Baldwin, 2001). That these regularities are detectable by infants might not be, from the perspective we have outlined here, altogether surprising. For one thing, such a system for statistically based parsing of action might be phylogenetically quite old (and thus unrelated to theory of mind). Furthermore, to the extent that there was additional selection pressure on infants during human evolution to act as if they possessed a mentalistic type of social understanding, then infants might have further elaborated upon this ability. They might have latched onto a specific class of regularities in the behavior of their caregivers that could be exploited – ones precisely coinciding with the intentional parsing of action made by our adult folk psychology (Baird & Baldwin, 2001).

Of course, one might counter that such heretofore unnoticed competences on the part of infants – competences that were only discovered by the application of procedures designed to probe for intentional understanding in infancy (see Table 2) – by themselves show that infants' understanding goes beyond what would be needed to exploit parents into providing more investment. After all, the abilities revealed by the research summarized in Table 2 might not be detectable by parents as they interact

with their infants. Conversely, however, one could argue that selection for behaviors that could be noticed by parents (the ones described above, and perhaps many of those listed in Table 1), might have carried with them precisely some of the ancillary skills developmental psychologists are now uncovering (e.g., see Table 2). It is also possible that more sophisticated research with parents might reveal that they do detect these subtle aspects of behavior without being aware that they do so.

Compounding the problem is the likelihood that at least two systems, or perhaps more precisely, two kinds of systems, might be operating in parallel in adult humans: one for detecting the statistical regularities in the behavior of others, and another system which maps intentional ascriptions onto that behavior (see Povinelli & Giambrone, 2000; Povinelli & Prince, 1998; from a human developmental point of view, see Baird & Baldwin, 2001). The difficulty arises in that independent of any selection for human infants to either actually understand (or act as if they understand) the intentional states of others, socially competent primates will have already evolved systems for detecting and analyzing many of the statistical regularities that exist in the behavior of others – precisely those regularities, in fact, upon which humans now map their intentional understandings (see Povinelli, 2001; Baird & Baldwin, 2001). If it is the case that such systems for detecting and using the fine-grained regularities in the behavior of the self and others existed long before theory of mind systems evolved, then it might be aspects of these systems, not the ones for reasoning about mental states, that were canalized earlier and earlier in human development in the manner predicted by parent-offspring conflict theory.

6 Future Directions and Conclusions

Parent-offspring conflict theory suggests that as a new system for social understanding (the ability to explicitly represent mental states) emerged in human evolution, a new arena for parent-offspring would have been opened, and human developmental systems would have responded in predictable ways. For example, competences for genuine social understanding might have been dragged earlier into ontogeny. Alternatively, other systems, which would lead infants to be perceived as if they possessed such competences, might have been modified or pulled earlier into development as well. Finally, some complex combination of the two processes might have occurred.

The framework we have outlined here adds to the already-existing list of possible explanations of behavioral patterns in infancy which resemble in important ways adult behavioral patterns. Our account does not necessarily make the methodological task of choosing among these alternative explanations any easier. When an infant exhibits a behavior that looks similar to a behavior in later development (e.g., smiling, pointing, following gaze, imitation), the early arising behavior might or might not have relevance to the pathway for a psychological system causally involved in the similar, later-arising behavior. Thus, our exploration of parent-offspring conflict theory offers developmental psychologists another principled, theoretical reason for delving deeper than the surface resemblance of behaviors in trying to understand the development of social understanding. One theoretical position particularly challenged by our model is the notion that very early in development infants possess an understanding or representation of the intentional dimension of behavior in themselves or others. Furthermore, it challenges traditional theoretical accounts of human development a seamless, causal transitions from earlier behaviors to later ones, in which these accounts see behaviors present at each successive age as the basic building blocks for later ones. Earlier behaviors, although structurally similar to later ones, might not, in fact, be the right causal precursors. One outcome of accepting the view presented here is that far more data need to be rallied, and especially data that have some hope of testing the hypothesized causal relationships between antecedent behaviors in infants and later developments in social understanding and theory of mind.

Our proposal might be extended by considering the possibility that theory of mind, although a specialization of the human species, appeared only gradually during the course of human evolution, or in a step-wise increments. We speculate that the emergence of even the earliest components of theory of mind in adults would have established the kind of selection pressures on human infants that we have discussed. Furthermore, because parent-offspring conflict is a continual, dynamic process (e.g., Trivers, 1974), once infants began evolving behavioral ‘imposters’ to exploit the adult’s theory of mind, adults, in turn, might have needed to advance their theory of mind skills in order to offset the resource losses brought on by their own infants’ behaviors. So, while behavioral ‘imposters’ might not play the kind of proximate causal role in the ontogeny of individual social understanding claimed by some researchers, these ‘imposters’ might nonetheless have played an evolutionary role.

The ontogenetic appearance of behavioral ‘imposters’ such as early gaze following, pointing, social smiling, and neonatal imitation might have caused the evolutionary honing of initial social understanding systems after these systems had started to appear in primate evolutionary history.

Acknowledgements

This research was supported by NSF Young Investigator Award SBR-8458111 and a Centennial Fellowship from the James S. McDonnell Foundation (JSMF) to DJP and JSMF 2002029 to TMP. Correspondence concerning this article should be directed to Daniel J. Povinelli, Cognitive Evolution Group, University of Louisiana at Lafayette, 4401 W. Admiral Doyle Drive, New Iberia, LA 70560.

References

- Albert, M. S., Diamond, A. D., Fitch, R. H., Neville, H. J., Rapp, P. R., & Tallal, P. A. (1999). Cognitive development. In F. E. Bloom & S. C. Landis & J. L. Robert & L. R. Squire & M. J. Zigmond (Eds.), Fundamental Neuroscience (pp. 1313-1338). San Diego: Academic Press.
- Altmann, J. (1980). Baboon Mothers and Infants. Cambridge, MA: Harvard University Press.
- Anderson, J. R. & Mitchell, R. W. (1999). Macaques but not lemurs co-orient visually with humans. Folia Primatologia, *70*, 17-22.
- Baird, J. & Baldwin, D. A. (2001). Making sense of human behavior: Action parsing and intentional inference. In B. Malle, L. J. Moses & D. A. Baldwin (Eds.), Intentions and Intentionality: Foundations of Social Cognition (pp. 193-206). Cambridge, MA: MIT Press.
- Baldwin, D. A., Baird, J. A., Saylor, M. M., & Clark, M. A. (in press). Infants detect structure in human action: A first step toward understanding others' intentions? Child Development.
- Bates, E., Camaioni, L., & Volterra, V. (1975). The acquisition of performatives prior to speech. Merrill-Palmer Quarterly, *21*, 205-226.
- Beaumont, S. L. & Bloom, K. (1993). Adult's attributions of intentionality to vocalizing infants. First Language, *13*, 235-247.

- Becker, J. C., Liersch, R., Tautz, C., Schlueter, B., & Andler, W. (1998). Shaken baby syndrome: Report on four pairs of twins. Child Abuse and Neglect, 22, 931-937.
- Bjorklund, D. F. (1987). A note on neonatal imitation. Developmental Review, 7, 86-92.
- Bloom, L. (1973). One Word At a Time: The Use of Single Word Utterances Before Syntax. The Hague: Mouton.
- Boesch, C. & Boesch-Achermann, H. (2000). The Chimpanzees of the Tai Forest: Behavioural Ecology and Evolution. Oxford: Oxford University Press.
- Buccino, G., Binkofski, F., Fink, G. R., Fadiga, L., Fogassi, L., Gallese, V., Seitz, R. J., Zilles, K., Rizzolatti, G., & Freund, H.-J. (2001). Action observation activates premotor and parietal areas in a somatotopic manner: an fMRI study. European Journal of Neuroscience, 13, 400-404.
- Butterworth, G. & Grover, L. (1990). Joint visual attention, manual pointing, and preverbal communication in human infancy. In M. Jeannerod (Ed.), Attention and Performance XIII (pp. 605-624). Hillsdale, NJ: Erlbaum.
- Butterworth, G. & Jarrett, N. (1991). What minds have in common is space: Spatial mechanisms serving joint visual attention in infancy. British Journal of Developmental Psychology, 9, 55-72.
- Call, J. & Tomasello, M. (2003). Social cognition. In D. Maestriepieri (Ed.), Primate Psychology: The Mind and Behavior of Human and Nonhuman Primates. Cambridge, M.A.: Harvard University Press.
- Camaioni, L. (1991). Mind knowledge in infancy: The emergence of intentional communication. Early Development and Parenting, 1, 15-22.
- Carpenter, M., Nagell, K., & Tomasello, M. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. Monographs of the Society for Research in Child Development, Serial No. 255, Vol, 63, No. 4.
- Chaminade, T., Meltzoff, A. N., & Decety, J. (2002). Does the end justify the means? A PET exploration of the mechanisms involved in human imitation. Neuroimage, 15, 318-328.
- Corkum, V. & Moore, C. (1998). The origins of joint visual attention in infants. Developmental Psychology, 34, 28-38.

- Dean, P., Redgrave, P., & Westby, G. W. (1989). Event or emergency? Two response systems in the mammalian superior colliculus. Trends in Neuroscience, 12, 137-147.
- Decety, J., Chaminade, T., Grezes, J., & Meltzoff, A. N. (2002). A PET exploration of the neural mechanisms involved in reciprocal imitation. Neuroimage, 15, 265-272.
- DiGirolamo, A. M., Grummer-Strawn, L. M., & Fein, S. (2001). Maternity care practices: Implications for breastfeeding. Birth, 28, 94-100.
- D'Entremont, B., Hains, A., & Muir, E. (1997). A demonstration of gaze following in 3 to 6-month olds. Infant Behavior and Development, 20, 569-572.
- de Waal, F. (1982). Chimpanzee Politics: Power and Sex Among Apes. New York: Harper & Row.
- de Waal, F. (1986). Deception in the natural communication of chimpanzees. In R.W. Mitchell & N.S. Thompson (Eds.), Deception: Perspectives on Human and Nonhuman Deceit (pp. 221-244). New York: SUNY Press.
- de Waal, F. (1989). Peacemaking Among Primates. Cambridge, MA: Harvard University Press.
- Donovan, W. L., & Leavitt, L. A., & Balling, J. D. (1978). Maternal physiological response to infant signals. Psychophysiology, 15, 68-74.
- Donovan, W.L., & Leavitt, L.A. (1985). Physiology and behavior: parent's response to the infant cry. In Lester, B.M., & Boukydis, C.F.Z. (Eds.), Infant Crying: Theoretical and Research Perspectives. New York: Plenum Press.
- Driver, J. Davis, G. Ricciardelli, P., Kidd, P., Maxwell, E. & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. Visual Cognition, 6, 509-540.
- Dykes, L. J. (1986). The whiplash shaken baby syndrome: what has been learned? Child Abuse & Neglect, 10, 211-221.
- Emde, R. N. & Koenig, K. L. (1969). Neonatal smiling and rapid eye movement states. Journal of the American Academy of Child Psychiatry, 8, 57-67.
- Emery, N. J., Lorincz, E. N., Perrett, D. I., Oram, M. W., & Baker, C. I. (1997). Gaze following and joint attention in rhesus monkeys (Macaca mulatta). Journal of Comparative Psychology, 111, 286-293.
- Feinman, S. (1982). Social referencing in infancy. Merrill-Palmer Quarterly, 28, 445-470.

- Field, T. M. (1977). Effects of early separation, interactive deficits, and experimental manipulations on infant-mother face-to-face interactions. Child Development, 48, 763-771.
- Franco, F. & Butterworth, G. (1996). Pointing and social awareness: Declaring and requesting in the second year. Journal of Child Language, 23, 307-336.
- Fries, W. (1984). Cortical projections to the superior colliculus in the macaque monkey: a retrograde study using horseradish peroxidase. Journal of Comparative Neurology, 230, 55-76.
- Frodi, A. M., & Lamb, M. E. (1980). Child abusers' responses to infant smiles and cries. Child Development, 61, 76-84.
- Gaulin, S. J. C. & McBurney, D. H. (2001). Psychology: An Evolutionary Approach. New Jersey: Prentice Hall.
- Goldenberg, G. (2001). Imitation and matching of hand and finger postures. Neuroimage, 14(1 Pt 2), S132-136.
- Goodall, J. (1986). The Chimpanzees of Gombe: Patterns of Behavior. Cambridge, MA: Belknap.
- Gopnik, A. & Meltzoff, A. N. (1997). Words, Thoughts, and Theories. Cambridge, MA: MIT Press.
- Haig, D. (1993). Genetic conflicts in human pregnancy. The Quarterly Review of Biology, 68, 495-532.
- Hains, S. M. J. & Muir, D. W. (1996a). Infant sensitivity to adult eye direction. Child Development, 67, 1940-1951.
- Hains, S. M. J. & Muir, D. W. (1996b). Effects of stimulus contingency in infant-adult interactions. Infant Behavior and Development, 19, 49-61.
- Hamilton, W. D. (1964). The genetical evolution of social behavior. Journal of Theoretical Biology, 7, 1-52.
- Hannan, T. E. & Fogel, A. (1987). A case-study assessment of "pointing" during the first three months of life. Perceptual and Motor Skills, 65, 187-194.
- Hare, B., Call, J., Agnetta, B., & Tomasello, M. (2000). Chimpanzees know what conspecifics do and do not see. Animal Behaviour, 59, 771-785.
- Iacoboni, M., Woods, R. P., Brass, M., Bekkering, H., Mazziotta, J. C., & Rizzolatti, G. (1999). Cortical mechanisms of human imitation. Science, 286, 2526-2528.
- Itakura, S. (1996). Manual action in infant chimpanzees: A preliminary study. Perceptual and Motor Skills, 83, 611-614.

- Johnson, M. H. (1990). Cortical maturation and development of visual attention in early infancy. Journal of Cognitive Neuroscience, 2, 81-95.
- Johnson, S. C. (2000). The recognition of mentalistic agents in infancy. Trends in Cognitive Science, 4, 22-28.
- Johnson, S. H. (2002). Cortical representations of human tool use. In S. H. Johnson (Ed.), Taking Action: Cognitive Neuroscience Perspectives on Intentional Movement (in press). Cambridge, MA: MIT Press.
- Johnson, S., Slaughter, V., & Carey, S. (1998). Whose gaze will infants follow? The elicitation of gaze-following in 12-month-olds. Developmental Science, 1, 233-238.
- Kaas, J. H., & Huerta, M. F. (1988). The subcortical visual system of primates. In H. D. Steklis & J. Erwin (Eds.), Comparative Primate Biology, Volume 4: Neurosciences (pp. 327-391). New York: Alan R. Liss.
- Kingstone, A. Friesen, C. K., & Gazzaniga, M. S. (2000). Reflexive joint attention depends on lateralized cortical connections. Psychological Science, 11, 159-166.
- Klaus, M. & Kennel, J. (2001). Commentary: Routines in maternity units: Are they still appropriate for 2002? Birth, 28, 274-275.
- Klaus, M. H., Kennell, J. H., & Klaus, P. H. (1995). Bonding: Building the Foundations of a Secure Attachment and Independence. Cambridge, MA: Perseus.
- Langton, S. R. H., & Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. Visual Cognition, 6, 541-567.
- Leavens, D. A. & Hopkins, W. D. (1999). The whole-hand point: The structure and function of pointing from a comparative perspective. Journal of Comparative Psychology, 113, 417-425.
- Leger, D. W., Thompson, R. A., Merritt, J. A., & Benz, J. J. (1996). Adult perception of emotion intensity in human infant cries: Effects of infant age and cry acoustics. Child Development, 67, 3238-3249.
- Lempers, J. (1979). Young children's production and comprehension of nonverbal deictic behaviors. The Journal of Genetic Psychology, 135, 93-102.
- Maestriperieri, D. (2002). Parent-offspring conflict in primates. International Journal of Primatology, 23, 923-951.

- Meltzoff, A. N. (1990). Foundations for developing a concept of self: The role of imitation in relating self to other and the value of social mirroring, social modeling, and self-practice in infancy. In D. Cicchetti & M. Beeghly (Eds.), The Self in Transition (pp. 139-164). Chicago: University of Chicago Press.
- Meltzoff, A. N. & Gopnik, A. (1993). The role of imitation in understanding persons and developing a theory of mind. In S. Baron-Cohen, H. Tager-Flusberg, & D. Cohen (Eds.), Understanding Other Minds (pp. 335-366). Oxford: Oxford University Press.
- Meltzoff, A. N. & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. Science, 198, 75-78.
- Meltzoff, A. N. & Moore, M. K. (1994). Imitation, memory, and the representation of persons. Infant Behavior and Development, 17, 83-99.
- Meltzoff, A. N. & Moore, M. K. (1997). Explaining facial imitation: A theoretical model. Early Development and Parenting, 6, 179-192.
- Moore, C., & D'Entremont, B. (2001). Developmental changes in pointing as a function of parent's attentional focus. Journal of Cognition and Development, 2, 109-129.
- Mosier, C. E. & Rogoff, B. (1994). Infants' instrumental use of their mothers to achieve their goals. Child Development, 65, 70-79.
- Morissette, P., Ricard, M., & Décarie, T. G. (1995). Joint visual attention and pointing in infancy: A longitudinal study of comprehension. British Journal of Developmental Psychology, 13, 163-175.
- Moses, L. J., Baldwin, D. A., Rosicky, J. G., & Tidball, G. (2001). Evidence for referential understanding in the emotions domain at twelve and eighteen months. Child Development, 72, 718-735.
- Murray, A. D. (1985). Aversiveness is in the mind of the beholder: perception of infant crying by adults. In Lester, B.M., & Boukydis, C.F.Z. (Eds.), Infant Crying: Theoretical and Research Perspectives (pp. 217-239). New York: Plenum Press.
- Nishitani, N. & Hari, R. (2000). Temporal dynamics of cortical representation for action. Proceedings of the National Academy of Sciences, 97, 913-918.
- Oppenheim, R. W. (1981). Ontogenetic adaptations and retrogressive processes in the development of the nervous system and behaviour: A neuroembryological

- perspective. In K. J. Connolly & H. F. R. Precht (Eds.), Maturation and Development: Biological and Psychological Perspectives (pp. 73-109). Suffolk, England: The Lavenham Press Ltd.
- Phillips, A. T., Wellman, H. M., & Spelke, E. S. (in press). Infants' ability to connect gaze and emotional expression to intentional action. Cognition. Academic Press.
- Plooi, F. X. (1978). Some basic traits of language in wild chimpanzees? In A. Lock (Ed.), Action, Gesture and Symbol: The Emergence of Language (pp. 111-131). London: Academic Press.
- Povinelli, D.J. (2001). On the possibilities of detecting intentions prior to understanding them. In B. Malle, D. Baldwin, & L. Moses (eds.), Intentionality: A Key to Human Understanding (pp. 225-248). Cambridge, MA: MIT Press.
- Povinelli, D.J. & Bering, J.M. (2002). The mentality of apes revisited. Current Directions in Psychological Science, 11, 115-119.
- Povinelli, D. J., Bering, J., & Giambrone, S. (2003) Chimpanzee 'pointing': Another error of the argument by analogy? In S. Kita (Ed.), Pointing: Where Language, Culture, and Cognition Meet. Lawrence Erlbaum.
- Povinelli, D. J. & Davis, D. R. (1994). Differences between chimpanzees (Pan troglodytes) and humans (Homo sapiens) in the resting state of the index finger: Implications for pointing. Journal of Comparative Psychology, 108, 134-139.
- Povinelli, D. J. & Eddy, T. J. (1996a). What young chimpanzees know about seeing. Monographs of the Society for Research in Child Development, 61 (2, Serial No. 247).
- Povinelli, D. J. & Eddy, T. J. (1996b). Chimpanzees: Joint visual attention. Psychological Science, 7, 129-135.
- Povinelli, D. J. & Eddy, T. J. (1997). Specificity of gaze-following in young chimpanzees. British Journal of Developmental Psychology, 15, 213-222.
- Povinelli, D. J. & Giambrone, S. (1999). Inferring other minds: Failure of the argument by analogy. Philosophical Topics, 27, 167-201.

- Povinelli, D.J. & Giambrone, S. (2000). Escaping the argument by analogy. In D.J. Povinelli (Ed.), Folk Physics For Apes (pp. 9-72). Oxford: Oxford University Press.
- Povinelli, D.J. & Giambrone, S. (2001). Reasoning about beliefs: A human specialization? Child Development, 72, 691-695.
- Povinelli, D. J. & Prince, C. G. (1998). When self met other. In M. Ferrari & R. J. Sternberg (Eds.), Self-awareness: Its Nature and Development (pp. 37-107). New York: Guilford Publications, Inc.
- Preuss, T. M. (1995). The argument from animals to humans in cognitive neuroscience. In M. S. Gazzaniga (Ed.), The Cognitive Neurosciences (pp. 1227-1241). Cambridge, MA: MIT Press.
- Rizzolatti, G., & Arbib, M. A. (1998). Language within our grasp. Trends in Neuroscience, 21, 188-194.
- Rizzolatti, G., Fadiga, L., Gallese, V., & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. Cognitive Brain Research, 3, 131-141.
- Sameroff, A. J. & Chandler, M. J. (1975). Reproductive risk and the continuum of caretaking casualty. In F. D. Horowitz (Ed.), Review of Child Development Research, Vol. 4 (pp. 187-244). Chicago, IL: University of Chicago Press.
- Scaife, M. & Bruner, J. (1975). The capacity for joint visual attention in the infant. Nature, 253, 265-266.
- Sparks, D. L., & Nelson, J. S. (1987). Sensory and motor maps in the mammalian superior colliculus. Trends in Neuroscience, 10, 312-317.
- Spitz, R. A. & Wolf, K. M. (1946). The smiling response: A contribution to the ontogenesis of social relations. Genetic Psychology Monographs, 34, 57-125.
- Sroufe, L. A. & Waters, E. (1976). The ontogenesis of smiling and laughter: A perspective on the organization of development in infancy. Psychological Review, 83, 173-189.
- Suddendorf, T. & Whiten, A. (2001). Mental evolution and development: Evidence for secondary representation in children, great apes and other animals. Psychological Bulletin, 127, 629-650.
- Symons, L. A., Hains, S. M. J., & Muir, D. W. (1998). Look at me: Five-month-old infants' sensitivity to very small deviations in eye-gaze during social interactions. Infant Behavior and Development, 21, 531-536.

- Thompson, R. A. (1987). Empathy and emotional understanding: The early development of empathy. In N. Eisenberg & J. Strayer (Eds.), Empathy and Its Development (pp. 119-145). New York: Cambridge University Press.
- Tomasello, M., Call, J., & Hare, B. (1998). Five primate species follow the visual gaze of conspecifics. Animal Behaviour, 55, 1063-69.
- Tomasello, M., Hare, B., & Fogelman, T. (2001). The ontogeny of gaze following in chimpanzees, Pan troglodytes, and rhesus monkeys, Macaca mulatta. Animal Behaviour, 61, 335-343.
- Trevarthen, C. (1979). Communication and cooperation in early infancy: A description of primary intersubjectivity. In M. Bullowa (Ed.), Before Speech: The Beginning of Interpersonal Communication (pp. 321-347). London: Cambridge University Press.
- Trivers, R. L. (1974). Parent-offspring conflict. American Zoologist, 14, 249-264.
- Tronick, E., Als, H., Adamson, L., Wise, S., & Brazelton, T. B. (1978). The infant's response to entrapment between contradictory messages in face-to-face interaction. Journal of the American Academy of Child Psychiatry, 17, 1-13.
- van Hooff, J. A. R. A. M. (1972). A comparative approach to the phylogeny of laughter and smiling. In R. A. Hinde (Ed.), Non-verbal Communication (pp. 209-241). Cambridge: Cambridge University Press.
- Vea, J. J. & Sabater-Pi, J. (1998). Spontaneous pointing behavior in the wild pigmy chimpanzee (Pan paniscus). Folia Primatologica, 69, 298-290.
- Watson, J. S. (1972). Smiling, cooing, and "the game." Merrill-Palmer Quarterly, 18, 323-339.
- Werner, W. (1993). Neurons in the primate superior colliculus are active before and during arm movements to visual targets. European Journal of Neuroscience, 5, 335-340.
- Whiten, A. & Byrne, R. W. (1988). Tactical deception in primates. Behavioral and Brain Sciences, 11, 233-244.
- Wolff, P. H. (1963). Observations on the early development of smiling. In B. M. Foss (Ed.), Determinants of Infant Behavior II (pp. 113-138). London: Methuen & Co. Ltd.
- Wise, S. P., Boussaoud, D., Johnson, P. B., & Caminiti, R. (1997). Premotor and parietal cortex: corticocortical connectivity and combinatorial computations. Annual Review of Neuroscience, 20, 25-42.

Woodward, A.L. (1998). Infants selectively encode the goal of an actor's reach. Cognition, 69, 1-34.

Woodward, A.L. (in review). Infants' developing understanding of the link between looker and object. Manuscript submitted for publication.

Table 1

Behaviors Susceptible to a 'Behavioral Imposter' Analysis

Behavior	Example Reference
crying	Leger, <i>et al.</i> (1996)
smiling	Sroufe & Waters (1976)
neonatal imitation	Meltzoff & Moore (1977)
deferred imitation	Meltzoff & Moore (1994)
sensitivity to contingency of others	Hains & Muir (1996b)
sensitivity to maternal still face	Field (1977)
sensitivity to being imitated	Meltzoff (1990)
sensitivity to varying affect intensities	Thompson (1987)
gaze alternation	Carpenter, Nagell, & Tomasello (1998)
gaze following	Scaife & Bruner (1975)
gaze re-direction	Bates, Camaioni, & Volterra (1975)
mutual gaze	Trevarthen (1979)
social referencing	Feinman (1982)
sensitivity to adult eye gaze	Symons, Hains, & Muir (1998)
conventionalized gestures	Butterworth & Grover (1990)
early word production	Bloom (1973)
proto-declarative pointing	Camaioni (1991)

Table 2

Selected Experimental Evidence Supporting the Idea of Early Social Understanding of Intentional States in Human Infants

Phenomenon	Reference
Encoding the goal of an actor's reach	Woodward (1998)
Parsing of the behavior stream at intentional joints	Baldwin, Baird, Saylor & Clark (in press)
Selective gaze-following of objects that establish contingency with infant	Johnson, Slaughter, & Carey (1998)
Connecting gaze and emotional expression to intentional actions	Phillips, Wellman, & Spelke (in press)
Connecting gaze and object of gaze	Woodward (in review)
Understanding referential of others' emotional outbursts in cases of discrepant focus	Moses, Baldwin, Rosicky, & Tidball (2001)