The recognition of mentalistic agents in infancy

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The ability to construe ourselves and others as agents with minds having mental states such as perceptions, attention, desires and beliefs, is critical to humans' social, linguistic, and cognitive competence. When and how this ability becomes available to us during development is therefore of particular theoretical importance. Historically, most work in this area has concentrated on the ability of three- and four-year-olds to predict and explain behaviors based on false beliefs. With recent advances in the methods available for studying cognition in pre-verbal infants however, more research is now focused on earlier age groups. In this review, arguments are presented for and against the presence of a rudimentary 'theory of mind' in infancy, with evidence discussed from three sources: (1) infants' active interactions with people; (2) infants' passive observations of people; and (3) infants' interactions with, and observations, of non-human agents.

One unresolved set of questions in cognitive science concerns the origins of such commonsense notions as 'object', 'number', 'space' and 'agent', upon which so many of our cognitive capacities are built. Are these notions given to us as part of our evolutionary heritage or are they acquired anew by each individual through personal experience in the world? How different from our own conceptions would those of fellow humans raised in an alternate universe actually be? How dependent on language is our conception of the world? While progress on these questions is slow, it is being made. One approach in particular is advancing – the study of concepts in infancy. Infants have relatively limited experience with the world and therefore provide one of our best windows onto the necessity of experience in conceptual development. Furthermore, because infants are largely non-verbal before the age of one-and-a-half to two years, their prelinguistic abilities may also give us insights into the role of language in concept representation. This review will focus on recent research aimed at uncovering the possible existence of the concept 'agent' in prelinguistic infants.

One of the most interesting senses of the concept 'agent', and the one that will be reviewed here, is the one entailing the possession of mental states. Mental states, and the minds that possess them, are necessarily unobservable constructs that must be inferred by observers rather than perceived directly. They are distinguished from other sorts of unobservables or internal states by the specific kind of relationship they hold with the world. That is, mental states are *directed at* the world; they are *about* things; they have content. They are what philosophers call 'intentional'[1]. Other commonplace, commonsense unobservables (e.g. life, essences, atoms, etc.), although presumed by lay thinkers to exist in the world, are not presumed to be *about* the world.

The ability to construe ourselves and others as agents with minds, replete with mental states such as perceptions, attention, desires and beliefs, is critical. With this ability we can communicate referentially, predict and explain others' behaviors, and manipulate both our own and others' mental states for the purposes of complex problem-solving and learning, not to mention deception. This ability is so critical in fact, that its absence is thought by some to be a central cause of autism[2–4].

Garnering evidence sufficient to demonstrate mental state attributions is difficult however. Many behaviors that could potentially serve as indices of mental state attributions (e.g. pointing) can typically be interpreted in both mentalistic and non-mentalistic ways. This is particularly true for the attribution of mental states that are correlated with reality (e.g. perception or goals.) The recognition of this problem led Dennett to suggest that the only convincing evidence for the attribution of mental states must come from successful reasoning about *false* beliefs, because false beliefs drive behaviors not otherwise predicted by reality[5]. Dennett's insight motivated a generation of research (typically called 'Theory of Mind' or ToM) on the development of successful false-belief reasoning in children between the ages of two and four years[6–10].

Although Dennett's point is well-taken, the absence of successful false-belief reasoning before the age of four, does not mean that younger children and infants do not attribute *any* mental states to agents; only that sufficient evidence for such a claim is difficult to generate. Most researchers grant children at least some mental state reasoning by the age of two, supported in part by the emergence of explicitly mentalistic vocabulary, such as the words '*want*' and '*see*'[11]. Consensus

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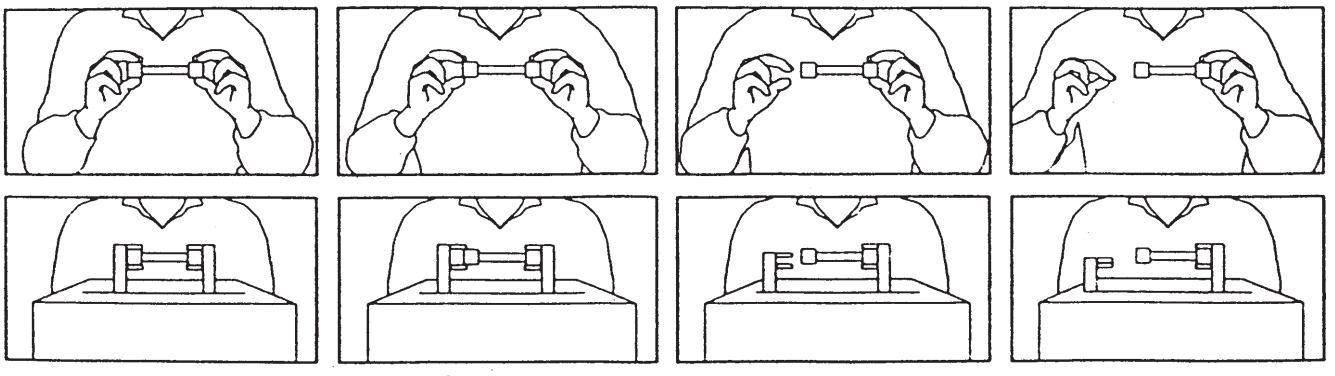

Fig. 1. Human and non-human demonstration of actions. Eighteen-month-olds who watched a human demonstrator attempt to pull apart a dumbbell but fail (top row), pulled the dumbbell apart themselves when given the opportunity. Infants who instead watched a pair of mechanical pincers perform the same spatiotemporal actions (bottom row) did not. Time is represented by successive frames from left to right. (Reproduced, with permission, from Ref. 30.)

among infant researchers, who must rely entirely on non-verbal evidence, is more elusive. Nonetheless, a growing body of converging evidence is leading many to reduce the age at which they are willing to grant infants the ability to attribute simple mental states such as perception, attention or goals.

This evidence comes from at least three general (overlapping) sources, each of which will be reviewed below along with related counter-arguments: (1) infants' interpretation of people as indexed by their active interactions with others – yielding gross dependent measures based on productive behaviors; (2) infants' interpretation of people as indexed by their passive observations of others – yielding subtle attentional measures; and (3) infants' interpretations of non-human agents. Less direct research exists in this third area, so both sorts of dependent measures will be discussed together.

Infants' interpretation of people: measures of active interaction

The onset of communicative gestures and joint attention behaviors between the ages of nine and 12 months is typically seen as the first plausible sign of mentalistic attributions. At this age infants begin reliably to produce and comprehend gestures such as pointing, showing and requesting[12–17]. Under the mentalistic view, these behaviors result from the infant's active attempt to direct the attention of others toward some aspect of the world. Around this age infants are also seen to follow the attention of adults by alternating their own gaze between adults and events or objects in the environment[13,18–20]. (Under very simplified conditions, infants as young as three months have also been shown to follow gaze[21,22].)

Evidence also comes from other domains, including early comprehension of the referential aspects of language and emotion. Baldwin has shown that 18-month-olds consistently restrict their interpretations of new words to the referents of a speaker's gaze at the moment of utterance rather than the referent of their own gaze[23–25]. Though 14- to 16-month-olds are not yet able to reliably make the correct mappings between a novel word and a referent when the object of the speaker's gaze conflicts with their own, they can nonetheless use the speaker's gaze to prevent themselves from wrongly mapping the word onto the object they themselves were attending to. Another study has shown even earlier understanding of the referents of emotions in 12-month-olds using similar methods[26]. Infants seem able to use their understanding of emotional reference as an index of an individual's desire by 18 months at the latest. Tomasello and colleagues[27] found that 18-month-olds could use a speaker's emotional expression to disambiguate the referent of a novel word from a series of sequentially presented objects, and Repacholi and Gopnik[28] showed that infants of the same age were able to fulfill an adult's request for food on the basis of that adult's previous emotional responses to the food choices.

Evidence for the comprehension of goal-directedness has also been found. For instance, Carpenter and colleagues found that 14- to 18-month-olds would readily imitate an adult's action if it were linguistically marked as purposeful ('*There!*') but not if marked as accidental ('*Whoops!*')[29]. Meltzoff also found evidence of a comprehension of goals in infants using an imitation technique[30]. In his widely-cited study, 18-month-olds manually reproduced the object-directed goals of adult modellers at rates far above those of spontaneous object manipulations, even in cases where the adult's goals were never actually achieved and therefore had to be inferred by the infants. In a control condition in which a set of mechanical pincers acted as the 'agent', infants failed to reproduce the incompleted action, thereby eliminating explanations in terms of characteristics of the objects or action-paths alone (see Fig. 1).

Infants' interpretation of people: measures of passive observation

Other possible evidence that infants attribute mental states to people is based on infants' tendency to increase their visual attention to novel objects or events that violate their expectations (see Box 1 for more details on this method). Using the violation-of-expectations method, Woodward and colleagues[31] found evidence that suggested an attribution of perception to people. They showed that seven-month-olds looked longer when a moving person collided with another person, than when inanimate objects were involved in the same collisions. Furthermore, Phillips and colleagues (cited in Ref. 32) reported evidence that 12-month-olds understand that desires (as indexed by facial expressions and direction of gaze) predict actions. They showed that 12-month-olds looked longer at a person who smiled at (expressed desire at) one object but then picked up a different object than at a person who smiled at and picked up the same object. (Similar results have been reported in which the investigators replicated

Box 1. The visual habituation paradigm

The visual habituation paradigm used in infancy research exploits the fact that infants tend to look longer at novel (or unexpected) events than at familiar (or expected) events (Refs a–d). If infants are shown a display repeatedly, their looking times will decline, presumably as a result of increasing familiarity with the display. Infants' visual attention to a new display will recover to the degree that they find it novel or different from the original. This fact can be used to tease apart the possible interpretations that infants assign to the events depicted in the displays. In studies of infant cognition, researchers are typically interested in testing whether infants interpret some given phenomena in terms of either surface, perceptual features or deeper, structural relations. Thus, one test event will be perceptually more similar but structurally more different to the habituation event than the other, and vice versa. If infants interpret the habituation event in terms of its deep structure, they are expected to recover more interest to the test event in which the deep structure changes, even if it is more perceptually similar to the original. This method has been used productively to examine infants' reasoning about objects (Refs d–f), number (Refs g–i), and mechanical causality (Refs j,k).

Woodward's study used the visual habituation method to test whether infants encode human actions in terms of the goals of the actor, or solely in terms of the spatiotemporal movements involved (Ref. l). A subset of her stimuli are shown in Fig. I to illustrate the logic of her design (but readers are referred to the article for complete details of control conditions and analyses). Half of the infants were habituated to a hand approaching one of two toys on a stage (Fig. I). In the test events, one of two things changed, either the spatiotemporal path of the hand, or its target object. Woodward reasoned that if infants encoded the hand's action as goal-directed (reflecting an agent-world relationship), test trials in which the goal changed should be more novel, and therefore more interesting, than those in which the path changed. Indeed, both five-and nine-month-old infants dishabituated to the change in the hand's target relative to the change in the hand's path. Infants habituated and tested on identical events in which the 'agent' was a perceptually similar rod instead of a hand, exhibited quite different patterns. In these conditions, neither age group dishabituated to the change in the target object of the rod, suggesting that they had not encoded the *relationship* between the rod and the object as an important aspect of the event.

These results suggest that even by five months of age, infants recognize that: (1) the behavior of some (but not all) entities is directed at the world; and (2) the identity of the entity's target is relevant, i.e. the content of the relationship is represented. We can therefore say that infants attribute an intentional relationship between the object and the world (i.e. one based on content).

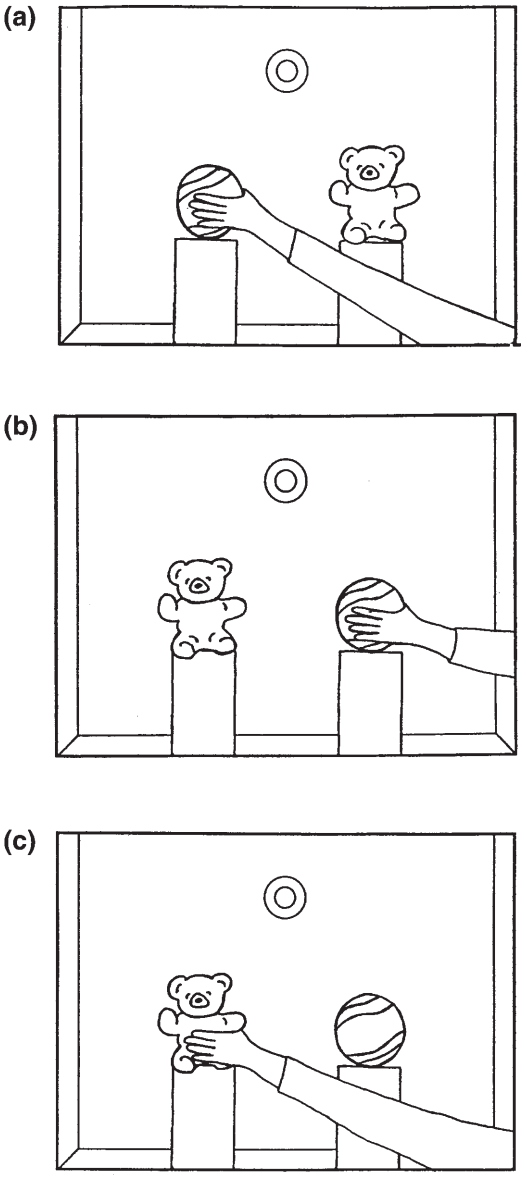

Fig. I. The hand condition of the visual habituation paradigm. (a) The habituation event. **(b)** The test event in which the hand's spatiotemporal path is changed, but its target object (goal) remains the same. **(c)** The test event in which the hand's target object (goal) is changed, but its spatiotemporal path remains constant. (Reproduced, with permission, from Ref. l.)

References

a Friedman, S. (1972) Newborn visual attention to repeated exposure of redundant vs 'novel' targets. *Percept. Psychophys.* 12, 291–294

b Slater, A. *et al.* (1984) Habituation in the newborn. *Infant Behav. Dev.* 7, 183–200

c Tighe, E. and Leaton, R. (1976) *Habituation*, Academic Press

d Spelke, E.S. (1985) Preferential looking methods as tools for the study of cognition in infancy. In *Measurement of Audition and Vision in the First Year of Postnatal Life* (Gottlieb, G. and Krasnegor, N., eds), pp. 323–363, Ablex

e Spelke, E.S. *et al.* (1992) Origins of knowledge. *Psychol. Rev.* 99, 605–632

f Baillargeon, R. (1994) How do infants learn about the physical world? *Curr. Dir. Psychol. Sci.* 3, 133–140

g Wynn, K. (1992) Addition and subtraction by human infants. *Nature* 358, 749–750

h Strauss, M.S. and Curtis, L.E. (1981) Infant perception of numerosity. *Child Dev.* 52, 1146–1152

i Starkey, P.D. *et al.* (1990) Numerical abstraction by human infants. *Cognition* 36, 97–128

j Leslie, A.M. and Keeble, S. (1987) Do six-month-old infants perceive causality? *Cognition* 25, 265–288

k Cohen, L.B. and Oakes, L.M. (1993) How infants perceive a simple causal event. *Dev. Psychol.* 29, 421–433

l Woodward, A. (1998) Infants selectively encode the goal object of an actor's reach. *Cognition* 69, 1–34

12-month-olds' tendency to dishabituate to a change in the goal of a perceiving agent. Furthermore, these researchers found that the effect was eliminated by a condition in which the agent's line-of-regard was occluded with a blindfold; B. Sodian and C. Thoermer, pers. commun.)

Using the same violation-of-expectations technique, Woodward has shown that even five-month-olds appear to have expectations regarding the goal-directedness of human hands relative to comparable inanimate objects[33]. Woodward familiarized five-month-olds to either a hand or a similarly configured rod repeatedly approaching one of two possible objects. The infants seemed to interpret the two displays differently, encoding the hand's movement in relation to the object it approached (i.e. its *goal*), but the rod's movement in isolation. This conclusion was inferred from the fact that they looked longer if the target object of the hand changed but not if the hand's approach path to the original target object changed. Their reactions to the same changes in the rod condition were just the opposite, that is they were surprised to see a rod change its pattern of movement, but not if the object it approached changed (see Box 1).

Interpretative problems

While the above evidence is suggestive of the recognition of mentalistic agents, the problem with granting anyone a notion of mentalistic agent on the basis of such evidence remains the same as that noted by Dennett (and described above): behaviors based on mental states that are correlated with reality (e.g. perception-guided behavior or goal-directed behaviors in the absence of false beliefs) can always be interpreted by the infant (or the scientist) in either mentalistic or non-mentalistic frameworks.

One leading alternative explanation for infants' apparent precocity in the studies described above invokes the presence of conditioned responses in the infant[8,20]. Throughout the first year the infant has ample opportunity to observe the covariation of people and actions in the world. In principle, for any given action that distinguishes the behavior of people and well-known inanimate objects, the infant could learn the appropriate associations without needing to impute mental states to people. Similar arguments apply to *any* common behavior an infant might engage in with other people, such as gaze-following, pointing, or other potentially communicative gestures. For instance, extensive experience interacting with their caretakers may condition infants to anticipate interesting events occurring in the direction of the caretakers' head turns[8,20]. In support of this position, Corkum and Moore demonstrated that gaze-following can be partially shaped by conditioning in eight- to nine-month-old infants who otherwise fail to follow gaze spontaneously[20]. Similarly, some authors argue that 12-month-olds' produce points and requests because of their instrumental effectiveness long before they are actually understood for their communicative nature[19].

On such accounts, it is not until the end of the second year, when infants begin to use language productively, that these theorists grant infants the ability to construe people as having mental states. Given the possibility of accounts such as these, as long as the agents used to test infants' competency are highly familiar to the infant, as are people, a non-mentalistic, conditioning explanation is impossible to rule out.

Most of the work in this area has nonetheless presupposed the role of people in infants' attributions of mental states. A small but growing body of work suggests that this presupposition may be unwarranted however, for theoretical reasons as well as methodological ones. A number of researchers have pointed out that knowledge domains that entail domain-specific reasoning (as the mentalistic domain seems to) may also entail domain-specific object-identification processes[34]. The object-identification processes leading to the recognition of a mentalistic agent could be isomorphic with the recognition of people, but they need not be.

Infants' interpretation of non-human agents: active and passive measures

Several theoretical proposals have been offered about the cues that lay thinkers, infants and adults alike, might use to identify the presence of mentalistic agents[2,34–39]. The features proposed fall into several overlapping classes; morphological features such as faces and eyes; asymmetry along one axis; non-rigid transformation; self-propulsion; and the ability to engage in contingent and reciprocal interactions with other agents. In general, the ability of infants to detect these features goes uncontested. However, the degree to which any of these features might serve specific functions in infants' reasoning in the mentalistic domain, as opposed to other domains (e.g. the social[40] or biological[41] domains) is still largely unknown.

Johnson and colleagues tested a subset of these potential cues and found that both the presence of a face, and contingently interactive behavior even in the absence of a face, proved powerful object recognition cues[39]. They tested the willingness of 12-month-olds to follow the 'gaze' of novel objects as a function of the cues embodied in the object. They found that infants were perfectly willing to follow the gaze of novel objects that either had a face, reacted contingently to them, or both. Interestingly, they failed to follow the gaze of the same faceless object producing exactly the same self-generated behaviors seen in the contingent condition, if those behaviors were not contingent upon the infants' own behavior. Based on this finding, Johnson *et al.* suggested that around the same age that infants seem able to attribute mental states such as perception and attention to people (12 months), infants are also able to attribute these mental states to novel entities other than people (see Box 2).

In other work that tested infants' interpretations of the behavior of non-human agents, Gergely and his colleagues showed that 12-month-olds develop visual expectations about the movements of computer-animated dots based on apparent interpretations of the dots' goal-directedness[42]. The dots in this study showed several putatively mentalistic characteristics, including non-rigid transformations, contingent interactions, and self-propelled motion. Schlottman and Surian[43] have also gathered evidence, based on visual-looking times, that young infants are capable of projecting mentalistic interpretations onto computer-animated, non-human agents. In their studies, nine-month-olds reacted with longer looking times if the apparent roles of two animated shapes were reversed, but only in the case where the roles were defined by a contingent interaction at a distance. (See also Ref. 44 for parallel logic and results in the physical domain.)

Box 2. Infants' attribution of attention to non-human agents

Johnson, Slaughter, and Carey (Ref. a) used a novel object to explore 12-month-old infants' attributions of mental states in a standard gaze-following paradigm (Ref. b). The object embodied many of the proposed cues for mentalistic agents, without being person-like. The size of a small beach ball, it was made of natural-looking fuzzy brown fur and had a naturalistic shape that was symmetrical along only one axis with a small cone-shaped bulge at one end (see Fig. I). It was designed to vary in two dimensions: the presence or absence of facial features and the quality of its behavior – specifically, whether or not its behavior was contingently interactive with the infant or not. Its 'behavior' was generated via a small remote-controlled beeper and incandescent light hidden inside it. Thus, it was possible to control the object from a hidden vantage point such that when the infant babbled, the object babbled back and when the infant moved, the internal light flashed in response.

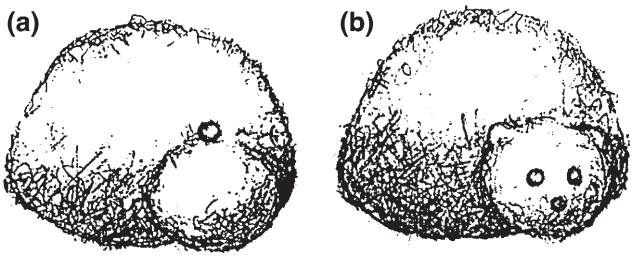

Fig. I. The novel object without a face (a) and with a face (b). (Reproduced, with permission, from Ref. a.)

Infants received a brief (60 s) familiarization period in which either the object reacted contingently to the infant's own behavior, or the infant saw equivalent amounts of apparently self-generated beeping and flashing, but in a sequence that was random with respect to the infant's own behavior. After this familiarization, the object made a final attention-grabbing beep and turned to orient itself towards one of two targets placed on either edge of the setup (see Fig. II). Infants were found to follow the 'gaze' of the object by shifting their own attention (as indexed by eye movements) in the same direction as the object's significantly more often than in the opposite direction in three of the four familiarization conditions: if the object had a face; if, when the infant babbled or moved, the object beeped back and flashed lights; or both of these conditions together.

Importantly, the object in the non-contingent, faceless condition embodied the same shape and movement cues as it did in the other conditions, but infants showed no reliable sign of following its 'gaze'. A further comparison condition with unfamiliar adults taking the place of the object suggested that infants were no more likely to follow the gaze of a contingently interacting person (with a face) than a contingently interacting fuzzy brown object with a face. Taken together, these results seem to show that infants use quite selective cues to decide when an object does or does not have a mind to perceive or attend with, specifically the presence of a face, or the propensity to interact contingently.

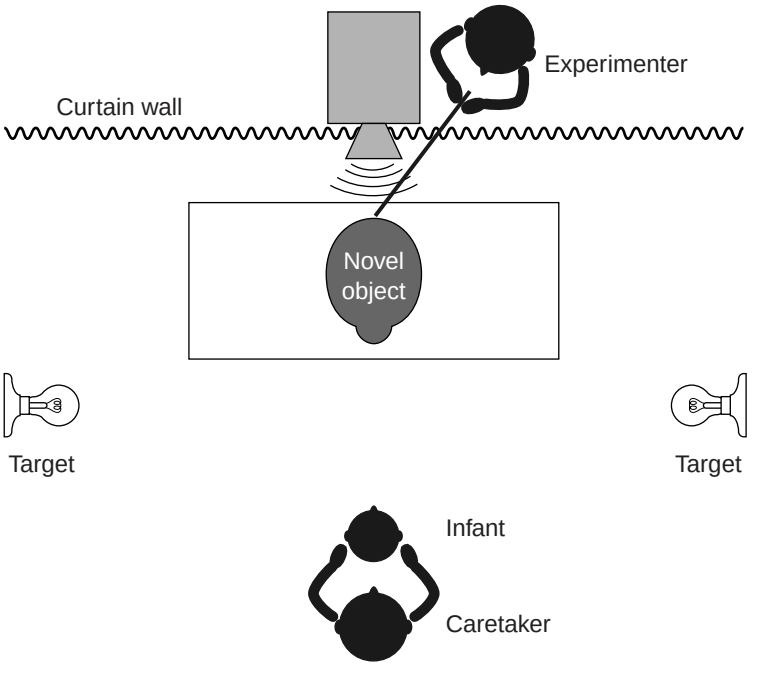

Fig. II. The gaze-following setup. After familiarization to the novel object, the object made an attention-grabbing beep and turned to orient itself towards one of two targets placed on either edge of the setup. Infants were found to follow the 'gaze' of the object to the relevant target significantly more often than they looked towards the opposite target, in three of the four familiarization conditions: if the object had a face; if, when the infant babbled or moved, the object beeped back and flashed lights; or both of these conditions together. (Reproduced, with permission, from Ref. a.)

References

a Johnson, S.C. *et al.* (1998) Whose gaze will infants follow? Features that elicit gaze-following in 12-month-olds. *Dev. Sci.* 1, 233–238

b Scaife, J.F. and Bruner, J.S. (1975) The capacity for joint visual attention in the infant. *Nature* 253, 265–266

It bears noting that two previously mentioned studies included non-human 'agents' as experimental controls – both Meltzoff's imitation study[30] and Woodward's hand-rod study[33]. In both cases, it was crucial to the interpretation of goal-attributions that infants treated the human agents and non-human control 'agents' differently. In neither case, however, did the control 'agent' clearly exhibit any of the putatively mentalistic cues mentioned above. Therefore, a domain-specific perception view such as that described above, would predict the same results. Consistent with this view, Johnson and colleagues have conducted a preliminary study using Meltzoff's methods, in which the non-human agent had a face and displayed contingent, self-propelled behavior. In this case, 15-month-olds did infer and reproduce the unseen goal of the non-human agent (S. Johnson, A. Booth and K. O'Hearn, unpublished data). Nonetheless, the existence of a specialized object identification process based on object cues, as opposed to *event* structures, has been questioned in a recent follow-up to the Gergely *et al.* study. In a second study, the animated dots themselves were stripped of all mentalistic cues and it was still found that infants interpreted their behaviors as goal-directed[45]. The exact difference between the agents (or events) in Meltzoff's and Woodward's studies on the one hand and this last study on the other is not yet resolved.

More interpretative problems

The existence of specialized object-identification processes for mentalistic objects would not in and of itself prove that infants have a mentalistic interpretation of those objects. For instance, some researchers have posited the existence of signal releasers (e.g. directional movement of the head or eyes) to account for early manifestations of gaze-following. Such mechanisms

would allow infants to share important information about the environment with caretakers without attributing a mind-world relationship to the gazer. Butterworth's ecological mechanism of early gaze-following depends heavily on infants' comprehension of the signal value in the adult's direction of gaze[46]. Similarly, based on work with chimpanzees, Povinelli and Eddy argue for an evolutionarily-shaped ability to follow eye gaze in the absence of attributions of perception[47]. In their study, chimpanzees who could follow the gaze of humans, did not use humans' gaze-direction to constrain their own requests. That is, they were just as likely to direct request gestures at humans whose vision was occluded as those who could see them. Corkum and Moore also suggest the existence of an inherent signal value in head turns based on evidence that eight-month-olds can be conditioned to follow gaze in the same direction as observed head turns, but not in the opposite direction[20].

The extent to which signal-releaser accounts can be generalized to other infant results (results based on overt behaviors such as imitation and passive measures such as looking time) that are at least superficially different from gaze-following remains to be seen.

Outstanding questions

- By the end of the first year, infants seem to distinguish between the kinds of things that are *directed at* the world – that have a relationship with the world that entails some form of 'aboutness' – and things that do not. How is this 'aboutness' relationship represented? Do one-year-olds construe agents as fully representational in the strong sense defined by Perner[50] or in some weaker, less representational sense such as that described by Wellman[51].
- If infants have a rudimentary 'theory of mind' by the end of the first year, where did it come from? Is it based on active knowledge construction from experientially derived data[9,30], an innate module or modules[2,36–38], or both, as recently suggested[52]? Is a notion of 'the self', distinct from 'the other', a prerequisite?
- Although infants are generally considered to be prelinguistic before the age of 18 months, they nonetheless belong to a species in which individuals are destined for the eventual aquisition of language. What, if anything, can we therefore conclude about the relationship between mental state attributions and language based on data from human infants?
- Relatedly, what can the study of other species, particularly non-human primates, tell us about the existence of mental-state attributions in infants or their relationship to language?
- What relationship, if any, exists between the sense of agent discussed here (i.e. *mentalistic* agent) and other senses such as *animate* agent (e.g. see Ref. 41) or *causal* agent (as found in linguistically motivated thematic roles, e.g. agent/patient)?

Conclusions

It is clear that the mechanisms underlying infants' recognition of, and interaction with, agents and what meaning, if any, infants attach to them, are not yet fully understood. Methodological progress on how to satisfy the evidentiary criteria for the attribution of mental states such as perception, attention, or goals has been slow. One point is clear however: non-mentalistic accounts, based either on conditioning or on signal releasers, give rise to the prediction that the infant's competency in this domain will vary across different behavioral contexts (e.g. gaze-following, communication and imitation). For instance, in an account based on conditioned associations, there is no reason to assume that the production of head turns as seen in gaze-following should correlate with measures of object manipulation as seen in imitation. Similarly, with signal-releaser accounts, different behavioral responses will depend on the existence of independent, evolutionarily specified mechanisms. Conversely, the degree to which putatively mentalistic attributions are manifested across a variety of diverse behaviors and contexts is evidence against non-mentalistic interpretations.

Thus, a general class of empirical strategies that will help to sharpen these predictions and decide between mentalist and non-mentalistic interpretations arises. Tomasello[12] and Dunham and Dunham[48] suggest that arguments for mentalistic attributions in infancy would be strengthened if it were shown that attributions across multiple behavioral contexts emerge within the same developmental window (e.g. see Ref. 13). Heyes, discussing a similar debate within the animal literature, suggests that the target attributions be demonstrated across multiple behavioral contexts within the same individual[49]. Finally, in my own work, I propose to strengthen the evidence for mentalistic attributions by attempting to elicit them across multiple behavioral contexts with the same restricted set of object recognition cues. That is, if the selective set of object features that elicit gaze-following in Johnson *et al.*'s study[39] do so because they invoke an intermediary representation (intermediary in the processing stream between perception and action) of mentalistic being, that representation should also be available to support other behaviors thought to be based on mentalistic attributions. If results consistent with mentalistic interpretations are obtained in divergent methodological paradigms, objections based on local interpretative issues of individual methods will no longer obtain.

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References

1 Lycan, W. Intentionality. In *MIT Encyclopedia of Cognitive Science* (Wilson, R.A. and Keil, F., eds), MIT Press (in press)

2 Baron-Cohen, S. (1995) *Mindblindness: An Essay on Autism and Theory of Mind*, MIT Press

3 Baron-Cohen, S. *et al*., eds (1993) *Understanding Other Minds: Perspectives from Autism*, Oxford University Press

4 Leslie, A.M. and Thaiss, L. (1992) Domain-specificity in conceptual development: neuropsychological evidence from autism. *Cognition* 43, 225–251

5 Dennett, D. (1978) Response to Premack and Woodruff: Does the chimpanzee have a theory of mind? *Behav. Brain Sci.* 4, 568–570

6 Wimmer, H. and Perner, J. (1983) Beliefs about beliefs: representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition* 13, 103–128

7 Gopnik, A. and Wellman, H. (1994) The theory theory. In *Mapping the Mind: Domain Specificity in Cognition and Culture* (Hirschfeld, L. and Gelman, S., eds), pp. 257–293, Cambridge University Press

8 Perner, J. and Lang, B. (1999) Development of theory of mind and executive control. *Trends Cognit. Sci.* 3, 337–344

9 Astington, J.W. *et al*. (1988) *Developing Theories of Mind*, Cambridge University Press

10 Leslie, A.M. (1994) Pretending and believing: issues in the theory of ToMM. *Cognition* 50, 211–238

11 Bartsch, K. and Wellman, H.M. (1995) *Children Talk about the Mind*, Oxford University Press

12 Tomasello, M. (1995) Joint attention as social cognition. In *Joint Attention: Its Origins and Role in Development* (Moore, C. and Dunham, A., eds), pp. 103–130, Erlbaum

13 Carpenter, M. *et al*. (1998) Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monogr. Soc. Res. Child Dev.* 63

14 Bates, E. *et al*. (1975) The acquisition of performatives prior to speech. *Merrill-Palmer Q.* 21, 205–226

15 Bretherton, I. *et al*. (1981) Early person knowledge as expressed in gestural and verbal communications: when do infants acquire a 'theory of mind'? In *Infant Social Cognition* (Lamb, M.E. and Sherrod, L.R., eds), pp. 333–373, Erlbaum

16 Lempers, J.D. (1979) Young children's production and comprehension of nonverbal deictic behaviors. *J. Gen. Psychol.* 135, 93–102

17 Butterworth, G.E. and Grover, L. (1988) The origins of referential communication in human infancy. In *Thought Without Language* (Weiskrantz, L., ed.), pp. 5–24, Oxford University Press

18 Scaife, J.F. and Bruner, J.S. (1975) The capacity for joint visual attention in the infant. *Nature* 253, 265–266

19 Butterworth, G.E. and Jarrett, N. (1991) What minds have in common is space: spatial mechanisms serving joint visual attention in infancy. *Br. J. Dev. Psychol.* 9, 55–72

20 Corkum, V. and Moore, C. (1998) The origins of joint visual attention in infants. *Dev. Psychol.* 34, 28–38

21 Hood, B.M. *et al*. (1998) Adult's eyes trigger shifts of visual attention in human infants. *Psychol. Sci.* 9, 90–93

22 D'Entremont, B. *et al*. (1997) A demonstration of gaze-following in 3- to 6-month-olds. *Infant Beh. Dev.* 20, 569–572

23 Baldwin, D.A. (1991) Infants' contribution to the achievement of joint attention. *Child Dev.* 63, 875–890

24 Baldwin, D.A. (1993) Early referential understanding: infants' ability to recognize referential acts for what they are. *Dev. Psychol.* 29, 832–843

25 Baldwin, D.A. (1993) Infants' ability to consult the speaker for clues to word reference. *J. Child Lang.* 20, 395–418

26 Baldwin, D.A. and Moses, L.J. (1996) The ontogeny of social information gathering. *Child Dev.* 67, 1915–1939

27 Tomasello, M. *et al*. (1996) Eighteen-month-old children learn words in non-ostensive contexts. *J. Child Lang.* 23, 157–176

28 Repacholi, B.M. and Gopnik, A. (1997) Early reasoning of desires: Evidence from 14- to 18-month-olds. *Dev. Psychol.* 33, 12–21

29 Carpenter, M. *et al*. (1998) Fourteen- through 18-month-old infants differentially imitate intentional and accidental actions. *Infant Beh. Dev.* 21, 315–330

30 Meltzoff, A.N. (1995) Understanding the intention of others: re-enactment of intended acts by 18-month-old children. *Dev. Psychol.* 31, 838–850

31 Woodward, A. *et al*. (1993) Infants expectations about the motion of animate versus inanimate objects. In *Proc. Fifteenth Annu. Cognit. Sci. Soc.*, pp. 1087–1091, Erlbaum

32 Spelke, E. *et al*. (1995) Infants' knowledge of object motion and human action. In *Causal Cognition: A Multidisciplinary Debate* (Sperber, D. *et al*., eds), pp. 44–78, Clarendon Press

33 Woodward, A. (1998) Infants selectively encode the goal object of an actor's reach. *Cognition* 69, 1–34

34 Carey, S. and Spelke, E. (1994) Domain-specific knowledge and conceptual change. In *Mapping the Mind: Domain Specificity in Cognition and Culture* (Hirschfeld, L.A. and Gelman, S., eds), pp. 167–200, Cambridge University Press

35 Carey, S. and Spelke, E. (1996) Science and core knowledge. *Philos. Sci.* 63, 515–533

36 Leslie, A.M. (1994) ToMM, ToBy, and Agency: Core architecture and domain specificity. In *Mapping the Mind: Domain Specificity in Cognition and Culture* (Hirschfeld, L.A. and Gelman, S., eds), pp. 119–148, Cambridge University Press

37 Leslie, A.M. (1995) A theory of agency. In *Causal Cognition: A Multidisciplinary Debate* (Sperber, D. *et al*., eds), pp. 121–141, Clarendon Press

38 Premack, D. (1990) The infant's theory of self-propelled objects. *Cognition* 36, 1–16

39 Johnson, S.C. *et al*. (1998) Whose gaze will infants follow? Features that elicit gaze-following in 12-month-olds. *Dev. Sci.* 1, 233–238

40 Watson, J.S. (1979) Perception of contingency as a determinant of social responsiveness. In *Origins of the Infant's Social Responsiveness* (*The Johnson & Johnson Baby Products Company Pediatric Round Table, II*) (Thoman, E.G., ed), pp. 33–64, Erlbaum

41 Gelman, R. *et al*. (1995) Distinguishing between animates and inanimates: not by motion alone. In *Causal Cognition: A Multidisciplinary Debate* (Sperber, D. *et al*., eds), pp. 150–184, Clarendon Press

42 Gergely, G. *et al*. (1995) Taking the intentional stance at 12 months of age. *Cognition*, 56, 165–193

43 Schlottmann, A. and Surian, L. Do 9-month-olds perceive causation-at-a-distance? *Perception* (in press)

44 Leslie, A.M. and Keeble, S. (1987) Do six-month-old infants perceive causality? *Cognition* 25, 265–288

45 Csibra, G. *et al*. (1999) Goal attribution without agency cues: the perception of 'pure reason' in infancy. *Cognition* 72, 253–284

46 Butterworth, G.E. (1991) The ontogeny and phylogeny of joint visual attention. In *Natural Theories of Mind: Evolution, Development, and Simulation of Everyday Mindreading* (Whiten, A., ed), pp. 223–232, Blackwell

47 Povinelli, D.J. and Eddy, T.J. (1996) What young chimpanzees know about seeing. *Monogr. Soc. Res. Child Dev.* 61

48 Dunham, P.J. and Dunham, F. (1995) Optimal social structures and adaptive infant development. In *Joint Attention: Its Origins and Role in Development* (Moore, C. and Dunham, P.J., eds), Erlbaum

49 Heyes, C. (1993) Anecdotes, training, trapping and triangulating: do animals attribute intentional states? *Anim. Behav.* 46, 177–188

50 Perner, J. (1991) *Understanding the Representational Mind*, MIT Press

51 Wellman, H.M. (1993) *The Child's Theory of Mind*, MIT Press

52 Scholl, B.J. and Leslie, A.M. (1999) Modularity, development, and 'theory of mind'. *Mind Lang.* 14, 131–153