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## Early Developments in Joint Action

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### Abstract

Joint action, critical to human social interaction and communication, has garnered increasing scholarly attention in many areas of inquiry, yet its development remains little explored. This paper reviews research on the growth of joint action over the first 2 years of life to show how children become progressively more able to engage deliberately, autonomously, and flexibly in joint action with adults and peers. It is suggested that a key mechanism underlying the dramatic changes in joint action over the second year of life is the ability to reflect consciously on oneself and one's behavior and volition and correspondingly, on the behavior, goals, and intentions of others.

### 1 Early Developments in Joint Action

Joint action takes a multitude of forms and occurs in a variety of systems and at multiple levels of complexity. There are many ways to achieve joint action, which at its broadest and most inclusive refers simply to the coordination of behavior in time and space between individuals without benefit of an outside physical connection. For example, schooling fish, herding buffalo, and flocking geese act together in precise synchrony that can be considered joint action, as does an audience of concert-goers clapping enthusiastically in unison at the close of a compelling performance. Emperor penguin parents, who protect their single egg from the deeply frigid Antarctic winter by cradling it on the tops of their feet under their insulating feathers, periodically exchange the egg, precisely aligning their feet and bodies and carefully coordinating complementary actions so that the precious egg never touches the icy ground and is only minimally exposed to the subzero temperatures. Human mothers and fathers take similar care in precisely coordinating a complex series of movements in handing over their newborn infant to one another, cradling its head, adjusting their posture, angling their arms just so, timing the transfer. During "rough- and-tumble" play, the young of many species including human children, romp together in complex, lengthy, integrated bouts of parallel and complementary actions skillfully coordinated in time and space to maintain mutual engagement and high levels of positive arousal without physical injury. The examples are legion, extending to the interactions between viruses and host cells; the division of labor among the residents of eusocial insect colonies like ants and termites; mutual courtship displays in some species of insects, birds, and mammals; and so on. Joint action has deep phylogenetic roots.

Although the varying forms and functions of joint action have been widely considered in many species, and have been the subject of thought and study in diverse fields of scholarship, remarkably little is known about the ontogeny of joint action. The current paper is concerned with the development of a relatively restricted part of this space - joint action

between human children as an intentional cooperative activity that the children consciously choose and manage on their own, deliberately coordinating their behavior toward a common aim. Whereas infants engage in joint action during social play with adults from early in life, regular occurrences of spontaneously generated, mutually sustained joint activity with peers does not emerge until the end of the second year of life, and even then is quite limited and rudimentary (Brownell and Brown 1992; Eckerman and Peterman 2001). Only later in the preschool years do children reliably adopt and coordinate multiple roles and actions with each other in joint play and problem solving, routinely negotiate and share goals, and support one another's activity with respect to their shared goals (Ashley and Tomasello 1998; Hamann et al. In press; Smiley 2001).

One difficulty in studying the development of this sort of joint action is how to determine when children are genuinely cooperating in the sense that both children's actions are consciously subordinated to intentionally shared goals. In an influential paper on the origins of shared intentionality, Tomasello and colleagues captured this challenge when they wrote "we do not know exactly how much of an understanding of intentional action is necessary for children to participate in collaborative activities" (Tomasello et al. 2005). Philosophers have proposed a variety of criteria for identifying shared intentions in adults' cooperative activity (e.g., Bratman 1992, 1993; Gilbert 2009; Searle 1990; Tuomela 2005), although they do not entirely agree among themselves about precisely what those criteria should be. Still more problematic for developmental psychologists, however, is that even those criteria on which scholars do agree entail quite complex forms of reasoning about one's own and others' possible actions and intentions, including complex, hierarchical, and shifting relationships between each other's actual and inferred goals and intentions, and rational decision-making in considering and enacting the necessary actions jointly. Such advanced representations and psychological processes are coupled with equally complex forms of communication that are themselves instances of joint activity and that are held to be necessary to establish shared intentions and negotiate higher order joint actions in the first place (Clark 2006).

The dilemma for developmental psychologists in adopting such criteria for studying cooperative activity in infants and young children arises from the fact that even infants engage in what appears on its face to be intentional, cooperative joint action long before they possess the requisite psychological structures. For example, in the first year of life, infants recognize adults' violations of expected interaction sequences in face-to-face dyadic social interaction (Adamson and Frick 2003). By 12 months of age they participate in reciprocal social games with adults such as peek-a-boo, rolling a ball back and forth, taking turns inserting shapes into a shape sorter, and in caregiving routines such as getting dressed, all of which depend on action coordination (Rheingold et al. 1976; Ross and Lollis 1987). By 12 months they also communicate intentionally with adults in coordinated ways both gesturally and vocally (Bates et al. 1975; Liszkowski et al. 2006). This puts us in the position either of arguing that infants - whose social and cognitive capabilities are relatively immature - must possess the sorts of complex, reflective social understanding and communicative skills that permit them to generate and manage shared intentions and joint actions in cooperation much like adults (e.g., Carpenter 2009), or of arguing that the criteria for shared intentions and joint action between adults are too complex to apply to young, cognitively naïve children, hence must be revised to a simpler or weaker form to accommodate the more primitive levels of social understanding and communication of infants and young children (e.g., Apperly and Butterfill 2009; Butterfill 2001; Tollefsen 2005).

Clearly, all sorts of joint activity is possible without conscious goal representations, complex reasoning, and advanced self-other understanding, as illustrated in the opening paragraph,

both in other species and in our own joint behavior as adults, some of which occurs outside of reflective awareness (e.g., Chartrand and Bargh 1999; Sebanz et al. 2006). In studying its development in children the problem is how to characterize and differentiate primitive, lower levels of joint action operationally from more complex and cognitively sophisticated forms. For example, one-year-olds recognize when their partner fails to take a turn during joint toy play with adults, and they attempt to re-engage the partner in the activity (Ross and Lollis 1987; Warneken et al. 2006), consistent with sharing a cooperative or joint goal with the partner. But during the interaction itself, their behavior is only minimally coordinated with the partner's (details below), and they often appear to be pursuing their own individual goals rather than joint or shared goals. Moreover, with a same-age peer partner infants never attempt to repair such failed turn-taking sequences (Brownell and Carriger 1991). Two-year-olds, in contrast, do coordinate behavior with a partner to achieve a goal, whether the partner is a peer or an adult (Brownell and Carriger 1990; Warneken et al. 2006). However, two-year olds make little effort to help a partner who has difficulty fulfilling his or her part in the cooperative enterprise; they thus seem unaware of any sort of joint commitment to a shared goal (Hamann et al. In press). At any given age, then, infants appear to be able to cooperate on some criteria, but unable to do so on other, closely related criteria. How can we reconcile such apparent inconsistencies?

In the absence of clear developmental models with age-relevant operational criteria to identify the degree to which intentions and goals are shared between very young children and their partners during joint activity, our research team has adopted a more bottom up, inductive approach. We ask how children's behavior changes with age in situations that afford or demand cooperative joint action; we then look for potential mechanisms to explain the age-related behavioral changes. We have concerned ourselves with how children come to be able to structure their joint activity with respect to one another and a single, external goal, and what might account for developmental changes in their growing ability to do so autonomously, without the input and guidance of adults. How does cooperative joint action develop between partners of equal understanding, skill, and motivation?

It will become evident that the ability to cooperate with peers, engaging in deliberate joint activity toward an external goal, emerges at the end of the second year of life. However, it is preceded by a lengthy apprenticeship in participating in joint action with adults. The following therefore begins with a brief, selective overview of empirical research on very early developments in infants' joint engagement with adults to show that the major transformations in their contributions to joint goal-directed action during the second year build on and arise out of their earlier apprenticeship in the first year. The subsequent section then reviews the work on developments in infants' joint action with other infants to show that the first instances of deliberate, cooperative joint action with peers emerge at the end of the second year. The final section turns to questions of mechanism, how one might account for the observed developmental patterns. The proposal is that joint action becomes more autonomous and flexible in late infancy and early childhood partly as a function of the growth of conscious self-awareness, the ability to reflect consciously on oneself as an object of others' perceptions, thoughts, and actions and simultaneously as an agent of one's own similar states and behavior. Indirect evidence for this position comes from research showing that children's cooperation with adults and peers exhibits rapid developmental change during the period when objective self-awareness also begins to emerge. Direct evidence for the hypothesis comes from several studies, ours included, that demonstrate relations between growth in self-other understanding and early developments in peer cooperation (Asendorpf and Baudonniere 1993; Brownell and Carriger 1990; Brownell et al. 2006; Hunnius et al. 2009; Smiley 2001).

## 2 Origins of Joint Action: Adult-Child Interaction

Joint action in its broad sense begins in the opening weeks of life during parent-child interaction. Parents draw their young infants into face-to-face interactive exchange, structuring and scaffolding social participation with an especially socially responsive infant in a dyadic “dance” that includes motor action, gazing, cooing, touching, and smiling along with other facial expressions. Indeed, a number of developmental scholars have argued that the human infant is uniquely prepared and motivated to become engaged in these affectively rich, highly arousing, and behaviorally contingent social interactions (Fogel 2001; Hobson et al. 2006; Reddy 2008; Stern 2002; Tomasello, et al 2005; Trevarthen 1979). Within this context infants become progressively tuned to the timing and structure of dyadic exchange (Bigelow and Walden 2009). Gradually, over several months, they come to anticipate and predict the partner’s affect and behavior in face-to-face dyadic activity. At the same time they learn how to coordinate and alternate their own attention, affect, vocalization, and motor action with responsive adult partners across an increasing variety of interactive contexts.

Participating in dyadic interaction with adults during the first months of life provides the young infant with the basic skills and expectations for joint action in social exchange, as well as the positive arousal that serves to sustain interest, engagement, and emotional commitment to interaction (Bornstein and Tamis-LeMonda 2001). Infants come to understand and interpret the signaling value of adults’ affect and behavior in routine social interaction, and acquire enormous amounts of practice in putting their growing understanding and skill to work in ways that garner positive emotional experiences. Notably, these very early instances of joint action do not require the infant to represent, infer, or consciously share the adult’s intentions, goals, or desires. The young infant must simply be interested in, engaged by, and responsive to the adult’s efforts to establish the joint action, i.e., be an attentive participant and respond to the other’s expressions and behavior. Indeed, infants are freely permitted by their adult partners to abandon these early interactions at will, unilaterally, whenever their interest flags or their arousal exceeds their regulatory capacities; their adult partners do not expect them to observe the norms and niceties of mature cooperative joint action.

During the second half of the first year of life, adult-infant dyadic interactions expand to include objects, events, and individuals outside of the dyad (Moore and Dunham 1995). For example, parents call infants’ attention to a toy by shaking it, banging it, and the like, and the infant follows the adult’s attention to focus on and play with the toy as well while also maintaining engagement with the adult; or the adult follows into the infant’s own attention to or engagement with an object so that together the two share the same activity, generating joint action. These triadic interactions are at first strongly tied to the immediate social and physical context, and occur in highly routinized action frames such as social games and play routines in which adults again structure the goals, content, and timing of the interaction and often direct the child how to behave in accordance (see also Carpendale and Lewis 2004). In this interactive context, infants come to share attention, interest, affect, and action with the partner in reference to something that they experience together, simultaneously. Adults scaffold and explicitly support this new form of joint activity when it emerges in the first year, and they continue to do so into the second year in challenging situations (Deák et al. 2000; Flom and Pick 2003).

Eventually, infants begin themselves to initiate joint action with adults and to respond in unique ways when adults violate their expectations for participation in the joint activity. For example, if a parent becomes distracted during peek-a-boo and fails to take her turn, 12-month olds may try to re-start the game by vocalizing to the adult or by re-enacting a well-

rehearsed part of the game such as placing the cloth over their own face and waiting. One-year olds also begin to point to interesting sights and events to share their interest and affect and they expect adults to respond appropriately by looking (Liszkowski, et al 2006). Thus, as joint action with adults develops in complexity over the first year, infants' contributions to and control over the structure of joint action also become more complex, along with advances in expectations for a partner's behavior and new skills for initiating and responding in more varied ways to others' behavior.

These exchanges with adults at the close of the first year form the foundation for dramatic growth in joint action during the second year of life, culminating in the child's ability to contribute autonomously to novel goal-directed joint action by the end of that year. Over this period children's joint engagement becomes progressively freed from adult guidance and structuring as their social understanding and interaction skills advance. This makes it possible for older toddlers and preschoolers to participate broadly in joint action across multiple social contexts and partners, and to generate and sustain goal-directed joint activity independent of adult direction. Although children participate in joint action from very early in life, they only gradually become autonomous contributors to it.

In a series of pioneering studies that first identified this general pattern of development, Bakeman & Adamson (Bakeman and Adamson 1984, 1986) followed infants from 6 to 18 months of age, observing them playing with their mothers and a standard set of toys. Mothers initiated joint engagement by following into the focus of infants' attention or by demonstrating an interesting object to capture infants' attention. They then complemented their infants' behavior with their own and helped their infants remain jointly engaged. Infants were jointly engaged with mothers in such exchanges up to 35% of the time by 15 months of age. Roughly half of that time involved a regular routine or action format so that most joint activity occurred in the context of specific, well-rehearsed scripts that specify the roles, behaviors, and timing for a given game or type of joint play (e.g., peek-a-boo; tickle; rhythmic games; chase). Thus, regular, familiar routines with their mothers supported infants' growing participation in joint action.

It was not until 18 months of age that every infant participated in at least one episode of what Bakeman and Adamson called 'coordinated joint engagement' in which the infant was an active participant in the interaction rather than being passively led by the mother's actions. As a proportion of total play time, this more complex and active form of joint engagement constituted only 11% at 15 months and only 27% at 18 months, but this was nevertheless substantially more than the 2–4% among infants of 12 months or younger (see Carpenter et al. 1998, for similar findings). So even though 12-month-olds are capable of engaging in joint attention such as following others' gazes and pointing (Bates et al. 1975; Liszkowski et al. 2006; Mundy and Willoughby 1996), active coordination of joint activity around toys and other objects, even with familiar, attentive, cooperative adults is not a regular occurrence until much later in the second year.

Similar findings were reported in a study of mothers' and infants' turn-taking games between 12 and 24 months of age, such as give-and-take play, rolling a ball back and forth, and the like (Hay 1979). Here, too, it was only at 18 months of age that the majority of infants actively participated in at least one coordinated game with their mothers. The number of such cooperative games was at floor at 12 months and more than doubled between 18 and 24 months. Moreover, the bulk of these were again routines and games that mothers had been playing regularly with infants for many months rather than novel games that required children to represent new forms of action and turn-taking roles. Indeed, in nearly half of the games, the child's role was simply to give or show a toy to the parent. Thus, cooperative games in which infants took an active role were extremely rare at the end

of the first year of life. By 18 months many, although not all, infants participated at least occasionally in such exchanges when they involved coordinating well-rehearsed actions within the envelope of familiar routines, and by 24 months this form of joint activity was a regular feature of mother-infant interactions.

In other studies of infants' contributions to coordinated interactions with mothers, Rutter and Durkin (1987) found that vocal sequences between mothers and infants were fully controlled by mothers before 24 months of age: children vocalized at will and mothers coordinated the turn-taking by altering their own vocal activity. After 24 months, however, children increasingly coordinated their own vocalizations with their mothers' by waiting their turn to vocalize and then doing so at the appropriate pause in the mother's vocal activity. The transition was somewhat earlier for gaze coordination, with rapid increases between 18 and 24 months in the sequencing of gaze. In particular, children began looking up at their mothers at the end of their own turns. Such "terminal looks" signal the partner that one's turn is finished and offer the floor for the next turn by the partner. Older children additionally looked at their mothers much more often at the end of the mother's turn, which permitted them to time and coordinate their behavior with the mother's turns. Thus, by 24–30 months of age, children had clearly begun to take an active role in coordinating and sequencing various types of joint activity with mothers.

More recent work confirms and extends these developmental patterns. Dix et al. (2009) found that 27-month olds were much more able to initiate and sustain positive involvement with their parents than were 14-month olds, by approaching, showing, pointing, vocalizing, or touching the parent, and by timing these behaviors to correspond to a parent's availability and responsiveness so that they resulted in mutual social exchange. In a longitudinal sample, Aureli (Aureli and Presaghi 2010) found that "unilateral" social engagement predominated early in the second year during mother-infant toy play, when mothers engaged infants' interest and attention while the infant simply watched without otherwise becoming actively involved with the object or theme. By the end of the second year, "symmetrical" engagement had become predominant, in which child and mother were jointly engaged, actively sharing attention, affect, and actions, and accommodating to and influencing one another. The decrease in unilateral engagement and the corresponding increase in symmetrical engagement occurred gradually over the second year with the latter surpassing the former only in the second half of the period. Thus, early in the second year children's contributions to joint action with adults around toys and other objects are not autonomous - one-year olds need the adult to direct and structure the joint part of the activity. This form of joint action is also relatively inflexible early in the second year, largely restricted to well-learned and practiced routines and games. In sum, the development of joint action in the form of active, coordinated engagement around common objects, to which the infant actively contributes, is an extended process that occurs under the tutelage of adults, with the first evidence of autonomy and mastery occurring toward the end of the second year.

One potential limitation in the conclusions we can draw from this research about the development of cooperative activity between young children and their adult partners is that the goals in such joint activities are not always evident because they aren't instrumental, physical-world goals. Instead, the "goal" of many social games is affiliation, simply to become and remain socially and emotionally engaged with one another. Of course, this is hardly a minor accomplishment and does require substantial coordination of many emotional and behavior components to maintain a smooth and mutually satisfying exchange (e.g., Shintel and Keysar 2009). Nevertheless, adult-child joint activity with an identifiable external goal whose achievement depends on the two partners coordinating their behavior, especially when the behavior is not routinized and highly practiced, may reveal more effectively the child's own contribution to the production of cooperative joint activity.

To this end, Warneken et al. (2006) designed novel cooperative games for 1- and 2-year-olds to play with adults. Each featured a set of standardized activities, and required two individuals to make something interesting or fun happen. For example, one task required partners to grip a small rubber ‘trampoline’ on opposite sides and shake it together to make a rubber ball bounce in the middle. Another required one person to push a small cylinder up through an opening to release a ball to the partner who had to retrieve it at the appropriate moment. Thus, the partners had to act together by positioning themselves appropriately in relation to one another and timing their own behavior in relation to the other’s actions. Across these non-routine tasks, 18-month olds’ behavior with the adult partner was rated as predominantly “uncoordinated” (vs. “coordinated” or “very coordinated”) and the children exhibited “low” cooperative engagement (vs. “medium” or “high”). On those tasks requiring children to anticipate the partner’s actions and to adjust their behavior accordingly, 18-month olds’ performance did not differ from chance. By age two, children operated at “medium” levels of cooperative engagement and were above chance in anticipating and coordinating their behavior with the adult. This age-related pattern roughly parallels those found in the research reviewed above that focused on more informal, affiliative forms of mother-child joint activity, although the child’s contribution to action coordination in unfamiliar situations with unfamiliar adults appears to be lower at age two than it is when engaged in familiar games and routines with mothers. Hence, when toys, activities, or partners are novel and unfamiliar, infants’ ability to coordinate their actions with an adult partner develops somewhat later, appearing in more rudimentary form at the end of the second year of life.

In sum, consistent with Vygotsky’s theoretical stance (1978) infants learn about cooperation by participating in joint action structured by skilled and knowledgeable interactive partners before they can represent, understand, or generate it themselves. Cooperative joint action develops in the context of dyadic interaction with adults in which the adult initially takes responsibility for and actively structures the joint activity and the infant progressively comes to master the structure, timing, and communications involved in the joint action with the support and guidance of the adult. Early on, infants are, in a sense, pulled into joint action by adults’ skillful efforts. Over the first several months of life they gradually take more control of and contribute more actively to joint dyadic engagement in face-to-face interactions. Later in the first year, joint actions become more complex as adults introduce objects into their interactions with infants and help them to coordinate their attention and actions with those of the adult around such objects. Initially, infants appear largely to be representing and pursuing their own ends in the context of this object-directed joint activity, while the adults help them transform these individual pursuits into cooperative engagement. Over the second year infants again gradually take more control of and contribute more actively to this new form of joint activity until they can initiate and manage their contributions themselves with minimal help and support from their adult partner. Eager participants from the beginning, it takes approximately 2 years for infants to become autonomous contributors to sustained, goal-directed joint activity as active, collaborative partners.

### 3 Development of Joint Action with Peers

If infants are able to participate in joint action by virtue of adults’ attentive and active scaffolding of their behavior, then what happens if the partner is not an adult? When and how does joint activity arise between young, naïve peers who have similar, primitive social understanding and comparable social skills? Are children able to manage joint action with a like-minded peer at the point that they can contribute autonomously and flexibly to cooperative joint action with adults, i.e., when adult scaffolding of joint activity gives way to mutually coordinated joint action at the end of the second year?

In some of the studies of mother-infant interaction reviewed above infants were also observed with an age-mate, and were found to engage in joint action several months later with peers than with mothers. At 18 months when every infant participated in at least one bout of coordinated joint engagement with mothers and a quarter of their play consisted of this more advanced form of joint action, only 7% of their play with a peer included any coordinated joint engagement (Bakeman and Adamson 1984). The joint action routines learned and practiced with each infant's own mother were not sufficiently general to be used to generate joint action with peers.

If the joint activity of one-year-olds depends on adults' structuring and scaffolding of infants' participation, then we ought to see significant limitations on cooperative action between one-year-old peers. Correspondingly, if children's ability at 24 months of age to initiate and maintain joint action autonomously with adults means that they have been freed of the immediate social and physical context and possess the requisite cognitive and social-cognitive abilities to generate joint action with any partner toward entirely novel ends, then we should see evidence of this in peer interaction as well.

Among familiar children in childcare groups, Holmberg (1980) found that coordinated actions between young peers during play were infrequent in the second year of life, but began to increase between 24 and 30 months of age. In a more rigorous, laboratory-based longitudinal study of children's ability to coordinate their actions with one another in sustained cooperative play around a common theme, Eckerman et al. (1989) showed that coordinated acts grew threefold between 16 and 28 months of age, with an especially sharp increase between 24 and 28 months. Notably, in the second year mutual imitation or chase/follow games constituted the bulk of children's joint activity; not until 28 months of age were they able to sustain joint action using more varied, non-routine, complementary actions that were related by virtue of a common theme or goal to which both children subordinated their individual acts, such as taking turns throwing things out of a playhouse window and retrieving them, while also chasing each other, exchanging gazes, and laughing together. These studies, along with smaller, more circumscribed ones (see Eckerman and Peterman 2001, for a review) have established that one-year-old children are quite limited in their ability to coordinate actions with each another in sustained interaction organized around shared play themes. Two-year-olds, in contrast, are capable of a wide variety of joint action with peers.

However, as in the mother-child interaction research, conclusions about the development of cooperative joint action in peer play are limited by our inability to discern clear, observable goals apart from basic social affiliation. Although children must coordinate complex sequences of action, affect, and attention in social games with one another, it is often difficult to identify what it is they are coordinating their behavior to accomplish, hence what the joint goal and shared task representation is, if any. Therefore, in experimental work on the development of peer cooperation, we have created tasks with simple, readily identifiable, objective, instrumental goals, such as getting a stuck toy out of a box, which can only be achieved via joint action. Tasks, goals, and requisite actions are standardized and structured to keep the cognitive, motivational, and motor demands to a minimum and within the range of competence of 1-year-old infants. The goal and the workings of the tasks are demonstrated by adults so that infants do not need to figure out and negotiate the goal or the actions necessary to achieve it. Thus, the only requirement to achieve the goal is that children be able to coordinate their respective actions spatially, by positioning themselves in relation to each other and the task, and temporally by timing their actions in accordance with their partner's actions and their relation to the goal. However, they must do all of this without benefit of a helpful adult partner and together with someone no more skilled or knowledgeable than themselves.



In an early study with 12- to 30-month old infants, children had to act together to retrieve small shareable toys from inside a clear box or cylinder (Brownell and Carriger 1990, 1991). One child had to push a handle to make the toys available at the opposite end of the box while the partner had to move into place to retrieve them. The task was constructed so that a single child could not perform both roles, i.e., push the handle and also access the toys. This meant that children had to position themselves in space opposite one another and perform different, separate actions in temporal sequence. We found that neither 12- nor 18-month olds could coordinate their actions with a peer to achieve this simple outcome. Although 12-month old dyads performed the relevant component actions such as pushing the handle and repositioning themselves in space, they did so independently of one another, apparently unaware of the possibility of acting jointly with the peer to get the toy. Half of the 18-month old dyads were successful once, but they were unable to reproduce their success. It was clear that their joint actions had been entirely unplanned, an accidental outcome of just happening to be performing the relevant actions while in the relevant locations. They were not attempting to consider their partner's behavior as they themselves were acting. Indeed, they could not even use their own serendipitous action coordination to reproduce the joint activity. In contrast, the 24- and 30-month olds were able to coordinate their actions deliberately and to cooperate successfully several times in succession.

Analyses of each child's individual behavior showed that 12- and 18-month olds were generally failing to consider the partner's position or actions with respect to their own. They rarely monitored their partner visually, often did not act when the partner was nearby and available, did not anticipate the partner's position or behavior or alter their own behavior accordingly, for example, by pausing while pushing the handle so that the partner could retrieve the toys. In contrast, 24- and 30-month olds were able to predict their partner's actions, movements, locations and to adjust their own behavior in anticipation, such as positioning themselves at the opposite end of the task just as the partner moved to one end. Thirty-month-old children were also more likely to gesturally direct or vocally command their partner to engage in a relevant action ahead of time, thus recognizing and acknowledging the partner's role and behavior in relation to their own and coordinating both vocalizations and behavior with the peer, perhaps even exhibiting an early attempt to divide labor.

Two-year olds, but not one-year olds, were able to act jointly with each other, on their own, in a novel situation, without the support of familiar partners, goals, or routines. This is not a minor achievement. To do so depends on the children attending to and anticipating one another's actions, considering the partner's actions in relation to one's own, and representing the state of the task and task outcomes as a function of each individual's behavior. These demands, it turns out, are especially difficult for one-year olds but are increasingly under the control of children age two and older.

In a more recent follow-up study to determine whether there were any circumstances under which 1-year-olds could cooperate with a peer, by reducing task demands to a minimum, the children each had to pull a handle while standing side-by-side, performing the same actions at the same time to activate a motorized toy (Brownell et al 2006). The goal or outcome was an exciting spectacle experienced in common, to reduce the possibility that the discrete objects that had to be physically shared in the prior study had introduced a competitive goal structure. Moreover, performing the same actions at the same time eliminated the possibility that the complementary and/or sequential joint action required in the prior study, or its hierarchical goal structure, was too cognitively difficult for the younger children. Finally, in another variant of the task infants were first trained to perform the actions individually on a one-child version of the task before being paired with the peer on the cooperative, two-child version.

Once more, 1-year olds coordinated their actions relatively infrequently compared to 2-year olds, failing to take their partner's behavior or location into account in deciding what to do and when to do it. For example, the youngest children more often operated their handle when the partner was doing something else and/or when the partner was away from the task. They mostly tried to achieve the goal by themselves, and did so even when joint action was impossible because they were all alone at the task. Indeed, many of the younger dyads could not coordinate their behavior even once. Although they occasionally produced coordinated behavior, their efforts were coincidental rather than cooperative. Thus, among one-year olds joint action with a peer was atypical and primitive.

By age two, however, children were considerably more skilled at coordinating their behavior with a peer partner. They more often operated the handle when the partner was also doing so, or was at least within reach of the other handle. They monitored their partner's behavior and accommodated to the partner's actions and location as they attempted to achieve the goal together. As a result their behavior was more often coordinated, and they were readily able to activate the toy. Two-year olds appeared to be actively collaborating in the sense of acting jointly to achieve a common outcome.

More recent studies of peer cooperation from other research groups, using similar kinds of tasks, have likewise reported that one-year old children are unable to act jointly to achieve a goal together whereas two-year olds can. For example, fewer than 25% of 19-month olds were able to coordinate their actions with each other to insert a ball into a colorful tube specially constructed to require joint activity (Hunnius et al. 2009). In a set of tasks modeled after those used by Warneken et al. (2006) for studying adult-child joint activity, 1-year-old peers could not coordinate their actions to achieve simple goals together after the task was demonstrated by adults (Steinwender et al. 2010). Even when the children had first been trained to cooperate with an adult, many were still unable to transfer coordinated behavior to the peer context. That is, they could participate in joint action with an adult, but they could not generate coordinated actions with a peer who did not support and guide the joint activity. Two-year-olds, in contrast, were able to coordinate their behavior with each other easily and with relatively little instruction or support from the adult.

## 4 Summary

All together this work shows that joint action with social partners does not simply increase in frequency or complexity over the first 2 years of life. Rather, it is transformed. Infants participate in joint action with adults well before they are able to understand or contribute actively and independently to it, with the adult partner structuring the interaction and scaffolding the infant's participation. By doing so, adult partners help infants to acquire the skills and understanding that permit them eventually to take on the role of an active partner who can contribute autonomously to novel forms of coordinated action. This occurs first dyadically, in face-to-face play and interaction beginning during the first few weeks and months of life between an emotionally engaged, responsive infant partner and a proactive adult partner who frames and supports the infant's engagement and manages the coordination of their respective actions. By the latter half of the first year infants can initiate and manage this form of joint action with adults, contributing actively to the creation and maintenance of coordinated activity in face-to-face dyadic interaction.

This opens the way for the emergence of triadic interaction at the end of the first year, a unique form of joint action in which partners act together on objects and events external to the dyad. Infants once more are largely passive partners in these joint activities, which are again structured and led by the adult partner. By the end of the second year, however, they

have begun to participate as active partners in this form of joint action as well, and do so across a variety of tasks and contexts.

The development of joint action with peers reflects and confirms the necessity of the adult's role in generating and controlling joint action in infants as they come to master the skills and understanding required to do so themselves, autonomously. Without the structure and scaffolding provided by the expert adult partner, 1-year-old children are unable to generate and sustain joint action with each other in the service of an external goal. By age two, however, they can do so readily, even with unfamiliar age mates and on novel, unfamiliar tasks.

## 5 Developmental Mechanisms

What developmental mechanisms might explain these changes in cooperative joint action over this period? To generate and deliberately coordinate joint action toward common goals children must be able to represent, monitor, and regulate both their own and their partner's behavior relative to each other as well as to their joint end. As a result many potential contributors and mechanisms are likely involved in its development, including cognitive (planning, memory, causal understanding), social-cognitive (understanding & sharing others' desires, goals, intentions), socio-emotional (prosocial motivation, inhibitory control, attentional control, basic interaction skills), and communicative skills, in addition to the actual mechanics of dynamically coordinating behavior in time and space with an active partner.

One necessary ingredient, we believe, is an objective self and the ability to reflect on self in relation to others, which begins to emerge during the second year (Brownell and Carriger 1990; Brownell et al. 2006). Zelazo has argued that the ability to reflect consciously and explicitly on one's own behavior permits the young child to become more "volitional," overriding habit and routine, freed from immediate contextual control of action (Marcovitch and Zelazo 2009; Zelazo 2004). Conscious reflection permits the child to maintain information about behavior and experience independent of actually producing or witnessing it, decoupling the content of experience from the experience itself (see also Perner 1991; Karmiloff-Smith 1992). This is necessary to deliberately select and produce outcome-relevant actions rather than responding automatically. It transforms the subjective experience of one's agency into an object of conscious consideration. Conscious awareness of one's own behavior and goals allows the child to imagine, plan, label, control, and correct behavior (Bullock and Luetkenhaus 1988). All of this also makes it possible to represent and consider one's own behavior in relation to another's, as well as in relation to one's own and another's ends (Barresi and Moore 1996; Kagan 1981; Moore 2007; Piaget 1952).

Barresi and Moore (1996) have proposed that an "intentional schema" develops in the second year of life in which children consciously reflect on and integrate subjectively derived information and knowledge about their own object-directed intentions and actions (1st person perspective) with objectively derived information about others' actions (3rd person perspective). In other words, in the first year of life, self and other are represented separately in terms of first and third person information respectively. But over the second year they are integrated and represented together within a single representational format. Self and other can thereby be related explicitly to one another in both thought and action (Zelazo 2004; Karmiloff-Smith 1992; Perner 1991). More specific to joint action, Tomasello et al. (2005) have invoked the construct of a "dialogic cognitive representation" to describe the common representational format that underlies and permits cooperative activities. Here both partners represent the other's goals and actions plans as part of their own goals and

action plans (after Bratman 1992). Both of these models entail conscious self-other representation at the levels of desires, goals, and intentions as well as actions.

Substantial evidence points to a major transformation in self-other representation during the latter half of the second year. Between 18 and 24 months of age, children become consciously, reflectively aware of themselves for the first time (Brooks Gunn and Lewis 1984; Moore 2007). The prototypical indicator is mirror self-recognition, in which the child recognizes himself as an identifiable individual and the mirror image as an objective representation of self separate from the actual physical self (Amsterdam 1972). Prior to this, the infant either ignores the mirror image or treats it as if it were another child. With the advent of mirror self-recognition, the child demonstrates that he can consider himself “from without,” from a third person perspective. Furthermore, to represent oneself as an object of others’ attention, perception, action, and the like also necessarily entails a simultaneous representation of the other’s attention, perception, and action.

We and others have suggested that children’s joint activity becomes progressively more controlled over the second year by this conscious, self-reflective system (Asendorpf and Baudonniere 1993; Brownell and Carriger 1990, 1991; Brownell et al 2006; Eckerman and Peterman 2001; Smiley 2001). The emergence of this system permits children to infer and to represent explicitly the causal, temporal, and spatial relations between the respective actions of self and a partner, to do so in advance of action and in relation to an external goal, and thus to act deliberately to coordinate behavior around that goal. Accordingly, young children become more able to take the partner’s goal-related activity into account in concert with their own and to adjust their own behavior by monitoring, timing, and sequencing their behavior together with adults and peers in relation to a common goal.

In support of this proposal, we have found that advances in infants’ ability to coordinate their behavior with one another are associated with multiple measures of developing self-other representations. One- and two-year olds’ symbolic representation of self and other in pretend play (e.g., pretending that a doll is feeding itself) was related to the amount of coordinated behavior they produced with a peer on the structured cooperation tasks described above (Brownell and Carriger 1990). Specifically, dyads in which at least one of the children produced advanced self-other representations in pretense were the only ones able to cooperate successfully to achieve the common goal. Similarly, children who were more advanced in sharing an adult’s attentional perspective (e.g., understanding and following adults’ referential points and gazes) more often monitored their peer’s behavior during joint activity, and more frequently and effectively coordinated their own behavior with the peer (Brownell et al 2006). And children who better produced and comprehended language about their own and others’ feelings and actions, and who could refer to themselves and others using personal pronouns likewise monitored their peer’s behavior more often and produced more joint activity with the peer (Brownell et al 2006). Thus, as children become progressively more able to represent and consciously reflect on self in relation to other, and vice versa, they also become more able to coordinate their behavior actively and autonomously with a range of others toward common goals.

Despite developmental advances in deliberate joint action toward a common goal, however, it should be noted that the dilemma of just how to characterize two-year olds’ understanding of the joint activity remains. That is, the “common” goal may or may not be shared in the strict sense defined by scholars of adult cooperative action and communication (e.g., Bratman 1992; Clark 2006; Gilbert 2009; Searle 1990; Tuomela 2005). This is reflected in the fact that even though two-year-old children’s joint activity with peers is autonomous and deliberate, in contrast to one-year olds, it is far from adult-like. For example, in our studies, two-year-old peer dyads produced uncoordinated behavior at rates similar to one-year-olds.

This took several forms, including leaving their side of the task to join the peer on the other side and preventing cooperation, or actively interfering with the peer's activity by taking over the peer's location and actions at one of the handles, or even turning away and departing altogether when the peer was in proper position for cooperation. Their actions often seemed to thwart the partner's efforts to achieve the goal. Rather than subordinating their individual actions to a joint intention to act together to achieve a shared goal, then, young two-year-olds may more simply be responding to the behavioral topology of the task in order to achieve their own goal. They can do so in a more sophisticated fashion than previously, by adjusting their behavior to the immediate task demands and opportunities, including the peer's current behavior and/or the outcome of the peer's behavior. With their more advanced understanding of action-outcome relations than younger infants, and of others as intentional agents of their own behavior, two-year olds may be able to figure out that their own efforts are more likely to be successful when the other child is in a particular location or engaging in a particular action, rather than understanding or caring that the two can share the goal. Here, the partner is a means to the child's own ends, albeit in a complex, coordinated series of one's own and the other's actions.

Other recent findings also suggest that 2-year-olds' joint action may reflect reasoning about how to coordinate their behavior with another to achieve their own ends without constructing a shared representation under which they work together to achieve a goal they hold in common. Hamann et al. (in press) showed that 2-year-olds could act jointly to retrieve toys from a box; but once one child had obtained a toy, that child ceased acting together with the partner, precluding the partner from likewise getting a toy. The goal in this case, although held by both children, seemed to be an individual one rather than shared, and the partner a convenient means to that individual end. In contrast, 3-year-olds persisted in the joint action until both partners obtained their toys, clearly sharing the goal. Grafenhain et al. (2009) found that 2-year-olds attempted to re-engage a partner who played next to the child if the partner stopped acting, even if the partner had not been acting jointly with the child on the same play material. Three year olds, on the other hand, recognized the difference between an adult acting in parallel next to the child and an adult acting jointly with the child; when play was interrupted they only attempted to re-establish joint activity with the latter.

Perhaps 2-year olds understand how others' behavior in such joint action contexts is relevant to their own ends, but not vice versa - how their behavior is relevant to the other's goal. Perhaps they can consciously represent their own and another's behavior in relation to one another, but only from the perspective of either their own goal or the other's, not yet simultaneously from both perspectives. Thus, in these apparently cooperative enterprises they may still be pursuing the goal individually, using the partner as a means to their own ends in a complex spatiotemporal, causal sequence of actions which does not necessarily include a higher-order representation of the joint task and shared goal that might govern their behavior.

In this vein, Butterfill (2007) has suggested that early forms of cooperative action ride on each child's understanding which behaviors by each actor contribute to the desired end result of their 'plural' activity, but do not require or depend on possessing genuinely shared task representations and commitments. Perhaps young children operate together under a "you and me," or perhaps more accurately "me with you," representation rather than a "we" representation (Gilbert 2009). Of course, it is also possible that 1- and 2-year olds do possess the complex self-other representations that constitute genuinely shared intentions, and we simply have not yet created the appropriate operations and empirical means for identifying them. Perhaps their apparent inability to generate joint action representations and to cooperate under such representations is due to unanalyzed task demands or motivational

barriers that obscure their underlying competence. Thus, although we have learned a good deal about the development of joint action, we do not yet know how young children represent a common goal, how much or which aspects of their task representations are shared and participate in controlling their behavior, or how their representations change with age as their participation in joint action is transformed.

## 6 Moving Forward

Many questions remain unaddressed concerning the ontogeny of joint action. What are the specific mechanisms that support infants' participation in joint action prior to their ability to represent and share the goals of a partner? To what extent do action and goal understanding in the first year of life develop out of infants' early experiences in joint action, and to what extent does such understanding transform infants' contributions to early forms of joint action? In the second and third years of life, how do children's representations of a partner's actions in relation to the child's own actions and goals become transformed into higher-order shared representations of tasks and goals? How does joint action itself change as self-other representations and inferences about others' knowledge, beliefs, and plans become more complex and abstract during early childhood? When and how does the child's ability to participate in joint action as a full partner develop still further into the ability to tutor others in the skills of acting together, progressing from collaborator to teacher?

Any system that requires or depends on joint action between or among actors must have neural and behavioral mechanisms for monitoring, predicting, and responding appropriately in space and time to others' behavior (Sebanz et al 2006; Sebanz and Knoblich 2009). However these need not be conscious and almost certainly are not in most examples of joint action in other species. A basic representational system that both distinguishes between and codes for similar and complementary actions by self and other must therefore underlie joint action even in its most primitive forms (Knoblich and Sebanz 2008). Among human adults, recent evidence suggests that during joint activity the partner's perspective on the world is implicitly calculated and represented in concert with one's own, outside of conscious awareness, and that this affects each individual's first-person cognitive processes and behavior (Samson and Apperly 2010; Sebanz et al 2006). This is interesting for developmental psychologists in that it provides a possible model and potential mechanism for the sort of implicit self-other representation that may govern the cooperative actions of the young infant in early interactions with adults. That is, perhaps infants build implicit, unconscious, dyadic representations that include the behavior of both self and other in relation to one another during their two-year-long joint action apprenticeship with adults.

However, much of human joint action requires that the partners are consciously, reflectively aware of their own actions, intentions, and goals and how they relate to those of others. It is this sort of deliberate, flexible, autonomously controlled joint action whose early development has been considered here. Studying the nature of the implicit self- and other representations of infancy, and how they become accessible to consciousness in concert with the development of secondary representations and reflective self-awareness, could move research on the ontogenetic origins of joint action forward in significant ways. At the same time, greater understanding of early developmental transformations in joint action, and the mechanisms that give rise to them, holds promise for elucidating how basic sensorimotor processes and representations inform, ground, and interact with higher level cognitive representations and executive processes to permit the remarkable range and complexity of joint action in older children and adults.

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