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PAPER

Continuity in social cognition from infancy to childhood

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Abstract

Research examining the development of social cognition has largely been divided into two areas: infant perception of intentional agents, and preschoolers' understanding of others' mental states and beliefs (theory of mind). Many researchers have suggested that there is continuity in social cognitive development such that the abilities observed in infancy are related to later preschool ability, yet little empirical evidence exists for this claim. Here, we present preliminary evidence that capacities specific to the social domain contribute to performance in social cognition tasks both during infancy and in early childhood. Specifically, looking time patterns in an infant social cognition task correlated with preschool theory of mind; however, no such relationship was found for infants in a nonsocial cognition task.

Introduction

Historically, the study of the development of the mind has focused on domain-general structures and processes (e.g. Piagetian and information processing theories). However, the last two decades have witnessed a growing interest in domain-specificity, in which the mind is represented as a group of specialized systems that process and represent specific kinds of information (e.g. Caramazza & Shelton, 1998; Spelke, 1994; Wellman & Gelman, 1998), and that, in some cases, develop in a continuous fashion over infancy and childhood (e.g. Carruthers, 2002). Perhaps owing to its ubiquitous importance throughout the lifespan, the domain of understanding the social world (i.e. reasoning about animate agents and their actions, intentions, beliefs, and desires) is often explored under this framework.

One particularly prominent example is research examining how infants and young children reason about social, animate entities, and importantly, how this may differ from their reasoning about nonsocial, inanimate entities. For example, infants interpret the actions of a human and a machine differently, imitating the underlying goals of the former but not the latter (Meltzoff, 1995). Similarly, they will interpret the action of a hand in terms of its goal-directedness, but the analogous motion of a stick in terms of its spatio-temporal path of motion (Woodward, 1998). Young infants even appear to differentially apply constraints of object physics to animate and inanimate entities; for example, they more readily apply the constraint of continuity of motion to objects than to humans (Kuhlmeier, Bloom & Wynn, 2004). These distinctions suggest that social stimuli are interpreted and represented differently from nonsocial stimuli in the infant mind.

Those studying slightly older children (e.g. 3- to 5-year-olds) similarly conclude that the cognitive processes underlying appropriate reasoning about the social world may contain elements distinct to this domain. It is commonly accepted that children, like adults, interpret behaviour within an intentional and mentalistic construal, and this 'Theory of Mind' (ToM) explains actions in terms of wants, needs, and beliefs (e.g. Gopnik & Wellman, 1994; Leslie, 1994; Wellman, 1990). Arguments for domain-specific elements in ToM come from a variety of sources, including, but not limited to, studies comparing performance on false photograph and false belief tasks (e.g. Sabbagh & Taylor, 2000; Slaughter, 1998) and studies of individuals with autism in which there is often a marked deficit in ToM independent of IQ level (e.g. Happe, 1995).

This leads to the following question: are the social cognitive skills seen in infant research related to those seen later in childhood ToM? Many researchers have suggested continuity in social cognitive development, and current theories range from ones positing a hierarchy such that infant abilities subserve and form the basis for later childhood abilities (e.g. Csibra & Gergely, 1998; Leslie, 1994; Meltzoff & Brooks, 2001; Olineck & Pulin-Dubois,

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2005; Povinelli, 2001) to those implying that some infant abilities are not qualitatively different from those seen in childhood (e.g. Johnson, 2003; Onishi & Baillargeon, 2005). Although these rich theories exist, there is little research that directly examines continuity specific to the social domain.

To date, infant-to-child developmental continuity has been demonstrated through relationships between infant cognitive abilities such as visual recognition memory, habituation, attention, and object permanence, and later, general childhood cognition (e.g. IQ, language) (e.g. Bornstein & Sigman, 1986; Colombo, 1993; McCall & Carriger, 1993; Rose & Feldman, 1997; Rose, Feldman & Jankowski, 2003, 2004). While these previous examinations factor into our current issue, they do not directly address domain-specificity. Instead, one approach to the current question is to look for a correlation between infant social task performance and later childhood ToM ability. For example, Wellman and colleagues (Wellman, Phillips, Dunphy-Lelii & LaLonde, 2004) took advantage of a post-hoc opportunity to examine a group of 4-year-olds who had previously participated in an infant task (at 12 months) examining the ability to discern gaze direction and desire (Phillips, Wellman & Spelke, 2002). The 4-year-olds were given a scaled battery of ToM tasks, and a significant relationship was found between infant looking time patterns and ToM performance. Specifically, infants who showed a larger looking time decrement in habituation trials performed better on the ToM battery. Importantly, no correlation existed between the infant looking time patterns and later verbal ability, suggesting some specificity in the relationship between infant and childhood social cognition. Similar results were found by Wellman, Lopez-Duran, LaBounty and Hamilton (2008).

The study by Wellman and colleagues (2004) serves as an important first step in examining the possible relationship between social cognition in infancy and childhood. Given the early stage of this research endeavour, the present study aims to build on this finding by providing another demonstration of continuity using a different type of infant social task. In the present study, we examine whether this correlation across development holds for children who as infants participated in a task that examined their ability to interpret goal-directed behaviour based on past actions and underlying dispositional states (Kuhlmeier, Wynn & Bloom, 2003). In addition, our study provides another comparison necessary to explore developmental continuity specific to the social domain: the relationship between infant nonsocial cognitive ability and later childhood social competence. Specifically, we examine the relationship between preschoolers' ToM performance and infants' looking patterns in a nonsocial task examining their ability to discriminate temporal durations of sounds. Correlated performance on both infant tasks and ToM would indicate that we are likely only tapping into individual differences in domain-general abilities. In contrast, if the social-cognitive abilities we see in infancy are related to childhood ToM by shared domain-specific elements, only performance across the same domain should be related.

Methods

Participants

Participants included 32 healthy 4-year-olds (mean age: 4;9, range: 4;3 to 5;3) who had previously participated in either the Infant Social or Infant Nonsocial Task. There was one participant who had participated in both the Infant Social and the Infant Nonsocial Task.

Infant social task

Our Infant Social Task group comprised children who had participated in Kuhlmeier, Wynn and Bloom (2003) as infants. In that study, 35 12-month-olds participated in a habituation procedure examining their ability to understand goal-directed actions and to interpret future actions based on previously observed behaviour. During habituation trials, infants were shown movies that depicted a computer-animated circle attempting to climb a hill. The circle was either helped up the hill by one object (e.g. a triangle) or hindered and pushed down the hill by another (e.g. a square). After habituation, infants saw two test movies that presented the same three agents, but in a different context. Infants looked significantly longer at test movies in which the circle approached the helpful object than those in which it approached the hindering object, indicating that they had distinguished between the helping and hindering agents during habituation and had specific expectations as to the subsequent actions of the circle in relation to them. Kuhlmeier *et al.* (2003) conducted two similar experiments in this study (Experiments 1 and 2), the second experiment serving to replicate the first under conditions in which the stimuli positions were reversed. Because there were no statistical differences between the two experiments, the participant groups were combined for subsequent recruiting for the preschool ToM task in the present study.

Of the 35 original participants in Kuhlmeier *et al.* (2003), 17 (10 from Experiment 1 and 7 from Experiment 2) returned for the ToM battery (mean age: 4;11, range: 4;5 to 5;1). In the original study, on average infants looked significantly longer at the 'consistent' test events by 2.27s, and the current sample showed the same pattern with a difference value of 1.80s. The returning group did not differ significantly from the original subject population ($t(50) = .58$, $p = .56$).

Infant nonsocial task

Children in the Infant Nonsocial Task group were recruited from among the 34 6-month-old infants who had participated in a duration discrimination study (vanMarle & Wynn, 2006).[1] In this study, the ability to discriminate lengths of tones at a ratio of 1:2 was examined using a habituation paradigm. Two versions of the experiment (Experiments 1 and 3) were completed, using tone durations of 2s versus 4s, and .5s versus 1s, respectively. Across both experiments and all conditions, after habituation to one tone (e.g. 2s), infants looked significantly longer after the novel duration (e.g. 4s) as compared to the familiar duration (e.g. 2s). Again, there were no statistical differences between the two experiments, and thus, both participant groups were combined for subsequent recruiting for the preschool theory of mind task.

Of the 34 original participants in vanMarle and Wynn (2006), 15 (7 from Experiment 1 and 8 from Experiment 3) returned for the ToM battery (mean age: 4;8, range: 4;3 to 5;3). Infants in the original study looked significantly longer at the novel temporal duration by 1.30s, and in the current sample, the average was 1.72s. Again, the returning group did not differ significantly from the original subject population ($t(47) = .007$, $p = .99$).

Procedure

Following Wellman and Liu (2004), the ToM battery included five tasks that ranged in difficulty and together evaluated children's abilities to understand others' knowledge states, desires, and emotions (Appendix 1). The tasks were administered in one of three pseudo-random orders, where the easiest task (Diverse Desires) was always the first or second task, and the most difficult task (Real–Apparent Emotion) was always the last or second to last task. Each participant completed all five tasks. On the battery, a child could score 0 (no tasks correct) to 5 (all tasks correct).

Measures for correlational analyses

Infant test preference

To measure the discrimination between the two types of test trials within each infant task, two kinds of preference scores were calculated. The 'Simple Preference score' was the difference between average looking time to the overall preferred event (i.e. preferred by the majority of infants) and the non-preferred event. Additionally, we included an 'Alternative Preference score' as suggested by Bornstein and Sigman (1986) and Wellman *et al.* (2004, 2008), which is the proportion of time spent looking at the overall preferred event across all test trials: the preferred test trials divided by the sum of the preferred and non-preferred trials. The two test preference measures are highly correlated: $r(17) = .94$ for the Infant Social Task and $r(15) = .90$ for the Infant Nonsocial Task. Here we include both measures for comparison with future studies; the Alternative Preference score may be more appropriate than the Simple Preference for 'preferential-looking' experimental designs where two events/stimuli are presented simultaneously and looking time to an individual stimulus is considered in relation to total looking at all stimuli.

Infant habituation decrement

Similar to Wellman *et al.* (2004, 2008) and following Bornstein and Sigman (1986), a measure of decrement of attention during habituation was generated by subtracting the sum of looking time for the last two habituation trials from the sum of the first two, and dividing by the sum of the first two trials.

Theory of mind performance

The dependent measure of the preschool ToM task was a cumulative score (with a possible range from 0 to 5) of how many items were answered correctly.

Results

Child theory of mind performance

Across both groups (Infant Social Task and Infant Nonsocial Task), the ToM Battery scores ranged from 1 to 5, $M = 3.41$ (.91 *SD*).[2] Particularly important for the correlational analyses that follow, there was no significant difference between the two groups in performance, $t(30) = .81$, *ns* (Infant Social, $M = 3.53$ (.87 *SD*); Infant Nonsocial, $M = 3.27$ (.96 *SD*)).

Correlational analyses

Test preference and theory of mind

For the Infant Social group, looking preferences in test correlated with ToM performance: $r(17) = .47$, $p = .05$ for the Simple Preference score, and $r(17) = .53$, $p = .03$ for the Alternative Preference score. Specifically, greater

[1] For reasons inherent to the theories underlying the individual infant studies that were used, the social cognition task was conducted at 12 months and the nonsocial cognition task at 6 months. For the present study, there may be concern that conceivably there is a higher correlation between measures taken closer in age. However, previous meta-analyses conclude that there are significant correlations between infant looking time patterns in nonsocial tasks at as young as 2 months and later general cognitive competence at 6 years and older, and that these correlations remain relatively stable throughout the intervening years (e.g. Bornstein & Sigman, 1986; McCall & Carriger, 1993; Rose, Feldman & Jankowski, 2004).

[2] We found that 63% of the children (20 of 32) followed the pattern of performance that fits the Five-Item Guttman Scale described in Wellman and Liu (2004). In their meta-analysis, 80% of children fit the pattern. The difference in performance in the present study may be due to the smaller sample size.

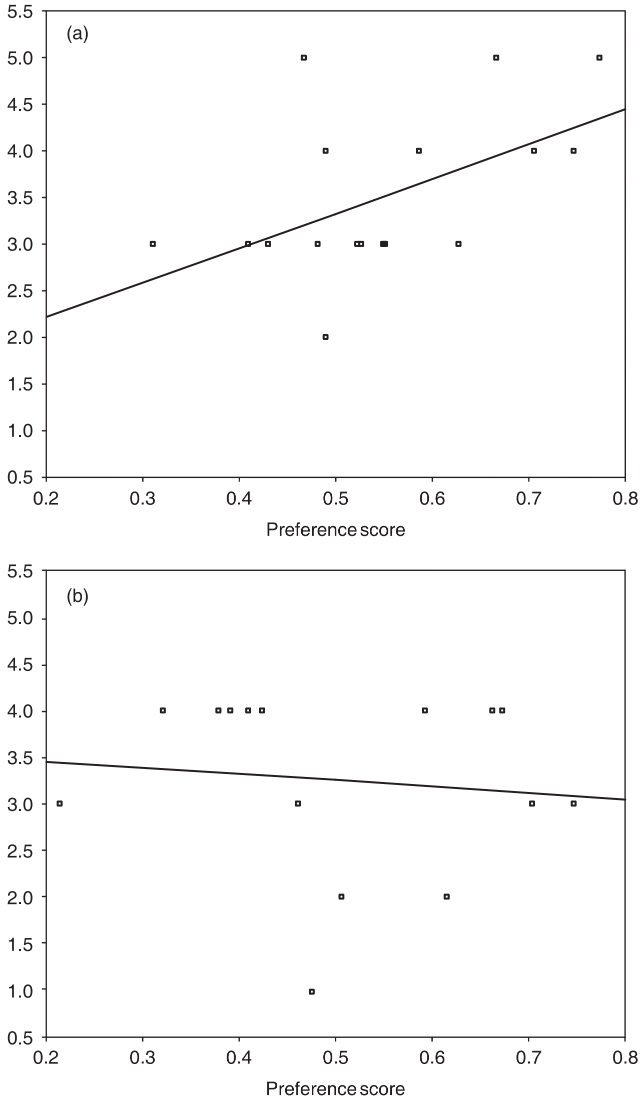

Figure 1 *Alternative preference score and theory of mind score (with best fit line) for (a) infant social task and (b) infant nonsocial task.*

looking time differences between the two test events during the Infant Social Task correlated with higher performance on the ToM battery. In contrast, this relationship was not found for the Infant Nonsocial group: $r(15) = -.09$, $p = .73$ for the Simple Preference score, and $r(15) = -.10$, $p = .69$ for the Alternative Preference score (Figure 1). That is, performance in the first year of life on a social cognition task, but not a nonsocial cognition task, correlated significantly with performance on a battery of theory of mind tasks at 4 years of age.

Habituation decrement and theory of mind

Given that the Infant Social Task can be characterized as a 'difficult' task (Kuhlmeier, Wynn & Bloom, 2006), and that approximately one-third (35%) of the infants in the present sample observed the maximum number of habituation trials, caution is advised in interpreting analyses using this variable. Decrement in attention during habituation for the Infant Social group was not significantly correlated with ToM performance, $r(17) = .33$, $p = .19$. However, this relationship was slightly stronger than that between the Infant Nonsocial group and ToM performance – $r(15) = .10$, $p = .69$ – though the difference was not statistically significant ($z_{Diff} = .62$, $p = .53$).[3]

Additional analyses

The Infant Social and Nonsocial samples were thus found to differ in terms of their relationships with childhood ToM. Two additional analyses were performed to ensure the validity of this finding. In order to be sure that our small samples were not being overly influenced by any 'extreme' members, we also performed the correlation analyses for test preference and ToM without including one participant from the Infant Social Task and one from the Infant Nonsocial Task who were 2.31 (Social Task) and 2.19 (Nonsocial Task) standard deviations above the mean for their group in the Simple Preference score. Excluding these cases did not affect the pattern of results. The correlation for the Infant Social Task group remained significant, and the Infant Nonsocial Task group remained nonsignificant: $r(16) = .49$, $p = .05$ for the Infant Social group and $r(14) = -.29$, $p = .32$ for the Infant Nonsocial group. No such extreme scores existed in the Alternative Preference score.

Additionally, the Infant Nonsocial group did not have a restriction of range relative to the Infant Social group. For the Simple Preference score, the Infant Social group had a range of 16.92s with an average of 1.60s (4.00 *SD*), and the Infant Nonsocial group had a range of 20.89s with an average of 1.31s (6.51 *SD*). Similarly, for the Alternative Preference score, the Infant Social group had a range of .46 with an average of .55 (.12 *SD*), and the Infant Nonsocial group had a range of .54 with an average of .51 (.16 *SD*). Thus, the correlation coefficients for the nonsocial group were likely not artificially reduced by limited variability in the dataset.

Discussion

The present study joins Wellman *et al.* (2004) and Wellman *et al.* (2008) in the first steps toward examining

[3] The correlation between the Infant Social test preference and ToM was also examined with habituation decrement partialled out. Since habituation decrements tend to be correlated with general intelligence (e.g. Bornstein & Sigman, 1986), it is possible that our habituation values index domain-general processing. Thus, this analysis offers a means of examining whether the relationship between test preference and ToM stands with a proxy for general intelligence controlled. The correlation remained unchanged: for the simple preference score $r(17) = .48$, $p = .06$, and for the alternative preference score $r(17) = .50$, $p = .05$.

continuity within social cognition, and extends the relationship between infant social cognition and later ToM to a different type of task. Additionally, we have tentatively demonstrated that this relationship may be one specific to *social* cognition. We will first address some of the important aspects of the current study design and then discuss the implications of the results.

One difference between the present study and that of Wellman and colleagues was the measures for which a relationship was uncovered. In Wellman *et al.* (2004), there was a significant correlation between infant habituation decrement and later ToM, but no such relationship between test discrimination and ToM. In the present study, the opposite was true for the Infant Social Task. It is not surprising that differences would be found, given other differences in the infant tasks used in the two studies such as the available cues to agency and the behavioural traits emphasized. Indeed, the fact that relationships with ToM were found with both of these infant social tasks – regardless of the differences in the stimuli used and precise social ability tapped – suggests that the relationship with ToM may be one that is specific to social tasks, yet perhaps not to one particular social-cognitive ability.

The current examination of domain-specific continuity is not without limitations. Because the study was conducted post hoc, we were unable to control for various elements in the two infant tasks such as modality of presentation (mostly visual vs. mostly auditory) and age of the participants (12 months vs. 6 months). In addition, the social task used test videos that diverge from a traditional habituation paradigm in which the 'familiar' test trials are exact replicas of the habituation trials. Instead, infants had to extract information from the habituation videos and then apply it to the new social scene depicted in the test trials. Future examinations would preferably match more equally the social and nonsocial tasks to more precisely address this question of domain-specificity.

There are of course likely cognitive processes that support domain-specific abilities (e.g. memory and processing speed; see Rose & Feldman, 1997, for a discussion of the developmental continuity of these abilities in nonsocial tasks), and these may or may not cross domain boundaries. In addition, it remains unclear which factors of infant attention (see Colombo, 2001, 2002) are responsible for the individual differences that appear in the infant tasks. Analogously, there are likely concomitant influences of domain-general cognitive abilities on childhood ToM. For example, many recent studies have reported a positive correlation between false belief task performance and executive functioning skills such as response inhibition and working memory (e.g. Carlson & Moses, 2001; Perner & Lang, 1999; Sabbagh, Xu, Carlson, Moses & Lee, 2005).

While recognizing the limitations of the present comparison, two implications are suggested from the current study. First, there are meaningful individual differences in social cognition that appear early and are developmentally stable, at least for the first 4 to 5 years of life.[4] Second, these may be domain-specific differences in reasoning, in that they may not stem from domain-general attentional or cognitive capacities that would have also affected performance on the Nonsocial infant task.

We will expand on this second point. The *specific* process or processes that lead to success on the infant task used in Kuhlmeier *et al.* (2003) or in Phillips *et al.* (2002) need not serve as *precursors* for later success on the types of tasks in the ToM battery. Instead, it is possible that abilities used in the infant social tasks are part of the same domain of cognition used in the ToM tasks, and that some individuals are stronger 'across the board' in this domain than others. How might we characterize the early abilities within this domain? Given the wealth of theoretical and empirical work on infant social cognition, there are many hypothesized candidate abilities that may bootstrap or develop into the abilities we see in childhood: detection of animacy cues (e.g. Baron-Cohen, 1995; Johnson, 2003; Leslie, 1994; Premack, 1990), specific attention to relevant features of animates (e.g. Klin, Jones, Shultz & Volkmar, 2003), processes of identification and imitation (e.g. Meltzoff, 2002), parsing of action into goal 'units' (e.g. Baldwin & Baird, 2001; Baldwin, Baird, Saylor & Clark, 2001), detection of goal-directedness (e.g. Leslie, 1994; Woodward, 1998), detection of dispositional states (e.g. Kuhlmeier *et al.*, 2003; Song, Baillargeon & Fisher, 2005), a teleological stance (e.g. Csibra & Gergely, 1998; Gergely, Nàdasdy & Csibra, 1995), and detection of gaze and gaze following (e.g. Baron-Cohen, 1995), among others. Broadly, we might speak of these as an interest in and attention to the social world that may differ across infants and ultimately cause some to be more observant and learn more about the social world than others (Wellman *et al.*, 2004, 2008).

At this point, the existent data demonstrate a possible relationship between infant social cognition and later theory of mind skills that may not hold for infant nonsocial cognition. The precise abilities that underlie this potential continuity in social development have yet to be determined. To more fully examine this question, systematic longitudinal studies would be required in which performance on multiple social and nonsocial infant tasks is compared within subjects to later ToM performance, as well as tasks that tap into domain-general cognitive capacities such as IQ and working memory.

[4] We do not, however, recommend that any *one* infant social task be used as a diagnostic tool for predicting later ToM abilities. Infant looking times can be variable for reasons other than an overall understanding of the concept tested (e.g. fatigue, etc.). Additionally, as mentioned, the present infant task examined only some of likely many social cognitive abilities related to later ToM.

Appendix

Descriptions for individual items in the theory of mind battery Wellman & Liu Scale (2004)

Test name	Description
Diverse Desires	Two people have diverging desires about the same objects.
Diverse Beliefs	Two people have diverging beliefs about the same object (independent of truth).
Knowledge Access	A person who has not looked inside a box cannot know what is inside.
Contents False Belief	A person has incorrect beliefs about the contents of a previously unopened but distinctive box.
Real/Apparent Emotion	A person can display an emotion that conflicts with or masks their true emotion.

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