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Contingency Is Not Enough: Social Context Guides Third-Party Attributions of Intentional Agency

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Four experiments investigated whether infants and adults infer that a novel entity that interacts in a contingent, communicative fashion with an experimenter is itself an intentional agent. The experiments contrasted the hypothesis that such an inference follows from amodal representations of the contingent interaction alone with the hypothesis that features of the experimenter's behavior might also influence intentional attribution. Twelve- to 13-month-old infants and adults observed a novel entity respond contingently to a confederate experimenter, the form of whose actions varied across conditions. For infants, intentionality attribution was assessed by the extent to which they subsequently followed the faceless entity's implied attentional focus. For adults, intentionality attribution was assessed from their use of psychological terms when later describing the entity's behavior. In both groups, construal of the entity as an intentional agent was limited to a subset of contingent interaction conditions. At both ages, the pattern of responses across conditions suggests that whether an observed contingent interaction can be seen as a social interaction influences the attribution of intentional agency. These results further indicate that the agent detection mechanism responding to third-party contingent interactions, as a context-sensitive process, is distinct from the mechanism responding to directly experienced contingent interactions, suggested by prior developmental work to be based solely on amodal representations of an entity's contingent reaction to behaviors of an infant.

Keywords: contingency, intentional agency, social interaction, social cognition, infancy

More than two decades of research has established that infants under age 2 are able to distinguish intentional agents—entities with mental states directed toward the world—from inanimate objects. Like adults, infants use representations of goals, attentional and perceptual states, and even epistemic states to reason about the observed behavior of the agents they encounter (e.g., Gergely, Nádasdy, Csibra, & Bíró, 1995; Luo & Johnson, 2009; Onishi & Baillargeon, 2005; Woodward, 1998).

One adaptive feature of the agent detection system is that it has multiple redundant paths toward identifying an agent in the world. Entities that look like people or animals or even ones that simply share some morphological features with known agents may be judged capable of holding intentional states (e.g., Yoon & Johnson, 2009). Other entities, even if they look nothing like a known agent, may be classified as agents on the basis of their behavior. For instance, 12-month-old infants will view even geometric figures as agents if their motion exhibits certain properties, such as repeated approach over various paths to a particular end point or efficiency relative to environmental constraints (Biro, Csibra, & Gergely, 2007; Gergely, 2010).

Infants are also attuned to a further behavioral trait that may be used to determine agency: an entity's capacity to respond contingently to its environment. Twelve-month-old infants follow the "gaze" of a novel object of ambiguous animacy, as long as it has a face, and they follow a faceless version that has interacted contingently with them by beeping and blinking a light in response to their vocalizations and hand waves (Johnson, Slaughter, & Carey, 1998; Movellan & Watson, 2002). If the object lacks a face and does not respond contingently to their behavior, infants do not follow its implied gaze. Because the infants participating in the experiments that demonstrated this phenomenon had had no prior history with the object, the authors suggested that morphological (e.g., its face) and behavioral (e.g., its contingent response) features can each be independently sufficient evidence for infants to infer that a novel entity is the sort of thing that possesses an attentional direction that should be followed; namely, an intentional agent.

In these studies, the behavioral evidence for the novel entity's intentional agency was the contingency of its behavior on the infant's own actions. Not all cases of contingency upon one's behavior signal another intentional agent (e.g., mirror reflections or the sound of a piano one is playing). Therefore, researchers have attempted to specify just what types of contingency do indicate a

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distinct agent. Watson suggested that a preference in infants from 4 months onward for high but imperfect levels of contingency serves to orient infants toward social objects in their environment (Gergely & Watson, 1999; Watson, 1972, 1979). More recently, Csibra and Gergely (2006) have proposed that infants are particularly sensitive to high but imperfect levels of contingency that possess the turn-taking structure typical of communication, from which they infer the presence of a communicative partner.

Other studies have demonstrated apparently similar attributions of intentional agency after infants merely observed a novel entity interact contingently with a confederate experimenter. After viewing a novel entity's contingent, beeping responses to an experimenter's speech toward it, infants both follow its "gaze" and even view its motion across a stage as goal directed (Johnson, 2003; Johnson et al., 2008; Johnson, Shimizu, & Ok, 2007; Shimizu & Johnson, 2004). Because infants appear to treat entities in similar ways whether they have interacted contingently with the infants themselves or with others, it is commonly assumed that the inference from contingency perception to agency attribution is mediated by the same cognitive mechanism in both cases. For instance, Johnson (2003) suggested that an entity's contingent responses provide information regarding agency by indicating that an entity is capable of perceiving events in its environment.

There are several reasons to question the assumption that directly experienced (infant/entity) and observed (other-agent/entity) contingencies engage the same agent detection mechanism. First, direct interactions may yield richer representations of a novel entity's contingency, as they offer the best opportunity to test and evaluate details such as the range of actions to which it responds (which is critical for determining its rate of response). Second, some theorists have hypothesized that judgments about an entity's agency made from directly experienced contingent interactions rely upon a suite of mechanisms selected through evolution for the specific purpose of helping an infant identify communicative partners for pedagogical interactions (Csibra & Gergely, 2006). If this account is correct, the relevant mechanism may operate only over representations of contingent interactions that involve the infant directly. Third, social information that infants are sensitive to in their own interactions does not always inform their interpretations of interactions among third parties. Cases where it does not include eye contact detection (Beier & Spelke, 2012), reasoning about what others have experienced (Moll, Carpenter, & Tomasello, 2007; Moll & Tomasello, 2007), and learning new words and actions (Floor & Akhtar, 2006; Herold & Akhtar, 2008; Király, Kreko, Kupán, Csibra, & Gergely, 2004).

One way to evaluate whether the same cognitive mechanism drives inferences from first- and third-party contingent interactions is to examine the information that affects the inferences in in each case. If infant/entity and experimenter/entity contingencies engage the same agent detection mechanism, then they should each do so over similar ranges of variation in how the contingency is demonstrated.

The weight of current evidence suggests that infants infer agency from abstract, amodal representations of directly experienced (infant/entity) contingencies. That is, the input from contingency perception relevant to agency detection is hypothesized to be unconstrained with respect to the modality or nature of the infant's actions (e.g., body movements, eye gazes, vocalizations) or of the potential agent's contingent responses (e.g., body movements, vocalizations). This is seen in the broad range of behaviors that have constituted the infant/entity contingencies established in different studies. In both Johnson et al.'s original study and one by Movellan and Watson, the novel entity's behaviors were beeps and flashes of light, and the infant's actions were pronounced body movements and vocalizations (Johnson et al., 1998; Movellan & Watson, 2002). More recently, 8-month-old infants followed the changing attentional focus of an animated, computer-generated entity whose motion had been contingent upon their direct eye gaze in a turn-taking manner (Deligianni, Senju, Gergely, & Csibra, 2011), and 12-month-old infants responded to the animated entity similarly when its motion had been contingent upon their leg kicks (Téglás, Kovács, Csibra, & Gergely, 2011). In Watson's original studies, in which infants' emotional responses to a novel contingent entity were reminiscent of their typical social responses to other people, the infants' actions were leg kicks or head movements and the entity's actions were motions (Watson, 1972; Watson & Ramey, 1972).

Investigations in which infants make third-party (experimenter/entity) observations of contingent interactions have not employed nearly the same variety in their demonstrations of contingency; in these studies, the experimenter has always talked to the entity, smiling at it and monitoring its response. It may be that these features of the experimenter's behavior, other aspects of the entity's response, or the context in which these occur have no bearing on inferences of agency from contingency. We would conclude in this case that a single, general mechanism relates contingency perception and agent detection and is sensitive only to the amodal structure of an entity's contingent behavior. It is also possible, however, that the particular actions that constitute a contingency or the context in which they occur contribute to infants' agency attributions. If representations of contingency leading to agent attribution included this information, they would not be amodal; consequently, we would conclude that infant/entity and experimenter/entity contingencies provide different forms of evidence for a novel entity's candidate agency and therefore engage distinct cognitive mechanisms.

In the experiments that follow, we investigate whether an experimenter's specific actions toward a contingently responding novel entity—namely, attending, smiling, and talking toward it—influence infants' and adults' attributions of agency. We tested the hypothesis that, in previous studies, the fact that the experimenter appeared to engage in a social interaction with the contingently responding novel entity influenced infants' responses. Although it has been shown that simply modeling conversational behaviors toward a nonresponsive novel entity does not lead infants to attribute intentional agency to it (Johnson, Booth, & O'Hearn, 2001; Johnson et al., 2007), no studies have yet investigated whether observing a novel entity respond with turn-taking contingency to a person whose actions do not have these social features will also lead infants to construe that entity as an intentional agent.

We adopted Johnson et al.'s (1998) paradigm for determining whether infants classify a novel entity as an intentional agent, whose attentional focus is both accessible and meaningful. We will refer to the alignment of an infant's gaze with the shifting orientation of the entity as "attention-following," remaining agnostic as to whether infants consider the entity's turns as more like looking or pointing (cf. Csibra, 2010; Johnson, 2003).

After replicating Johnson et al.'s (1998) basic findings, Experiments 1–3 introduce several new conditions that hold the contingency between the entity's and experimenter's behaviors constant while varying other aspects of the experimenter's behavior (and thus whether the interaction can reasonably be seen as a conversation or some other social interaction, or whether the experimenter shows an interest in or reaction to the agent's behavior). If infants attribute agency based upon abstract, amodal representations of other-agent/entity contingencies, these modifications should not affect their attention-following responses. If, however, the particular behaviors constituting an other-agent/entity contingency also inform the agent detection process, infants may not follow the entity's attention in all cases. If this were true, it would provide evidence that directly experienced (infant/entity) and observed (experimenter/entity) contingencies engage different agent detection mechanisms. Experiment 4 investigates whether adult participants' patterns of agency attributions across a similar range of conditions reveal traces of the same agent detection mechanism that is operational in infancy.

Experiment 1

In Experiment 1, we sought to replicate the finding that infants follow the attentional focus of a novel entity that has participated in a contingent "conversation" with an experimenter but that they will not do so when the novel entity has acted in a manner that is not contingent upon events in its environment (Johnson, 2003; Johnson et al., 1998, 2008). A new condition tested whether infants would take as evidence for intentional agency a contingent interaction in which the experimenter displayed familiar nonverbal social gestures toward the novel entity, or whether identifying a novel entity as an intentional agent requires observation of verbal contingent interactions. For this condition, the experimenter clapped his hands playfully while looking and smiling at the novel entity's forward-facing end, a social game that adults often direct toward infants at this age. In all conditions the novel agent's behavior was the same: It emitted beeps in a set pattern, and it had a light that flashed in synchrony with its beeps.

Method

Participants. Seventy-five 12- and 13-month-old infants participated in the study (mean age = 54.8 weeks, range = 50.0–60.4). There were 25 participants in each of three conditions (conversation: 14 female; person silent: 12 female; hand clap: 14 female). An additional nine infants were run but not included (eight due to fussiness and one to parental interference). For Experiments 1–3, the majority of infants were from middle-class backgrounds; most were identified as White. The families of participants were identified through commercially available lists and public records from the greater Boston area and were initially recruited by letter. A small toy and $5 travel reimbursement were provided for participation.

Apparatus. The infant sat on his or her caregiver's lap, 100 cm in front of a stage. The stage was a black horizontal surface 73 cm high, inset from a black curtain wall that extended from floor to ceiling. The stage area was 91 cm wide and 33 cm tall. Two freestanding target objects were positioned 20 cm in front of and 13 cm to either side of the stage. These target objects were white $13 \times 13 \times 64$ cm stands, with a laminated piece of yellow paper emerging from the top end. A 60-W lamp was placed within each stand toward its top end and angled such that it could illuminate the yellow paper from behind, creating an event that the infant would find interesting but not overwhelming. The lamps for each target object were connected to a single power line that was controlled by the puppeteer, so that they always turned on and off simultaneously.

The novel entity sat at the front and center of the stage (see Figure 1), with a black wall behind it. The surface material of the entity was short, brown synthetic fur. The entity had the approximate shape of a $23 \times 14 \times 15$ cm box with curved edges, with a smaller oval cushion affixed to its front end. As shown in Figure 1, the entity's animal-like status was ambiguous; the brown fur and headlike front piece are animal features. In these respects, the current entity resembled the original Johnson et al. (1998) entity more than those of Johnson's later experiments (Johnson, 2003; Johnson et al., 2007, 2008; Shimizu & Johnson, 2004). On the top side of the front end of its main body sat a 1.3 cm translucent red plastic protuberance, which housed an LED that was easily visible when illuminated. Both the LED and a pure tone buzzer, placed inside the entity's body, were connected to a power source that was controlled by the puppeteer, so that the entity always blinked and beeped simultaneously. Standing behind the wall behind the novel entity, the puppeteer controlled the movement of the entity by means of a short stick that emerged from its rear end and continued through a hole in the wall.

Procedure. At the start of each session, the novel entity was visible on the stage and the target lamps were turned off. While standing directly between the infant and the stage, the experimenter pointed to each of the targets in turn, saying, "Look over here," while the puppeteer turned them on and off. Once the infant had fixated upon each of the targets, the experimenter got into position for the interaction with the novel entity. He kneeled down on the floor, slightly to the right side of the space between the infant and stage, so that the infant could see both the novel entity and the experimenter's face in profile.

Infants were assigned to one of three interaction conditions. In the *conversation* condition, the experimenter initiated a 60-s conversation with the novel entity (modeled after a script provided by Johnson). After each line spoken by the experimenter, the novel entity responded with a series of short and long beeps. For each line, a natural response to the experimenter was first written in words and then converted to beeps by an approximation of that line's sequence of syllables. Thus, the duration of each of the entity's responses was variable, and the overall interaction possessed the turn-taking flow of a natural conversation. Throughout the interaction, the experimenter looked and smiled at the entity, displaying interest in its response to his speech.

In the *hand clap* condition, the experimenter initiated a playful interaction with the novel entity by clapping toward it, much like the turn-taking clapping game often played with infants around this age. The number and rhythm of the experimenter's claps were based upon his utterances in the conversation condition, in a manner similar to the original determination of the entity's beeping pattern. Following each clapping phrase, the entity responded with exactly the same series of beeps that it would have emitted at that point in the conversation condition. In this way, we were able to maintain the level of contingency between the experimenter's and

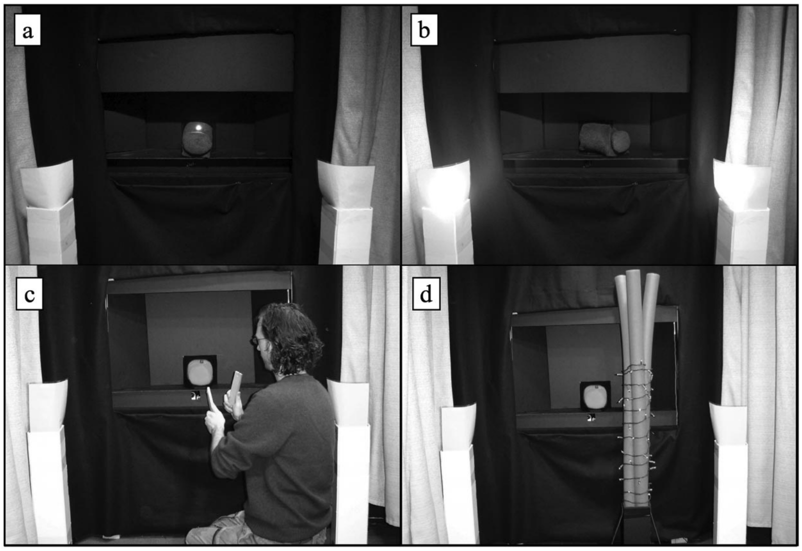

Figure 1. The experimental setup. The top two images present the novel entity used with infants (Experiments 1–3): (a) facing forward and beeping/blinking, and (b) after its turn, with side lamps illuminated. The bottom two images present the novel entity used in Experiment 4 with adults, during the interaction phase of the (c) stick clap and (d) novel object conditions.

the novel entity's actions across conditions, while varying the type of action performed by the experimenter. Throughout the 60-s interaction, the experimenter looked and smiled at the entity, displaying interest in its response.

In the *person silent* condition, the experimenter looked down at the floor in front of the stage. He remained silent and motionless in this position while the novel entity performed the same series of beeps as in the other two conditions, with appropriate pauses where the experimenter would have spoken or clapped.

Following the interaction, the experimenter stood up and walked to a position behind the caregiver's chair, where he was out of sight of the infant. At this point, following instructions given earlier, the caregiver also closed her eyes for the remainder of the session, to avoid biasing the infant's response. The entity then beeped a few times to capture the infant's attention and turned smoothly and quickly about 45 degrees to one side. As it reached the end of its turn, both target lamps came on. After 8 s, the lamps turned off and the entity turned back to face forward. It completed this sequence of beeping and turning four times in total, in an ABBA order. The direction of the first turn was selected randomly for each infant.

Although the target lamps in Johnson et al. (1998) did not turn on during the test phase, pilot testing suggested that turning them on after the entity's turn drew infants' looks further away from the entity, making coding easier. Thus, our presentation may be seen as a hybrid of overt attention following and directional attentional cueing (as in Hood, Willen, & Driver, 1998). Because the two lights turned on simultaneously, this modification does not change the basic logic of the procedure.

Scoring. For Experiments 1–3, a primary coder performed a frame-by-frame analysis of the video recordings for each infant (30 frames per second) and documented all eye movements that occurred during the 8-s window of each test trial. All eye movements judged to move from the novel entity in either horizontal direction (to the left or to the right) were counted as looks. Following previous studies (Johnson et al., 1998, 2008), we did not require infants to successfully locate the target objects for their eye movements to count as looks. Eye movements moving straight up and down from the entity or moving smoothly and uninterruptedly to the caregiver or the space behind her chair were not counted. From the coder's measurements, we constructed difference scores over the time spent looking in the direction consistent with the entity's orientation minus time spent looking in the opposite direction. A secondary coder recoded the recordings of 30 participants (10 per condition); coder agreement was high (Pearson's $r =$ .90).

The literature on infants' attention-following responses has used a number of different metrics. The most common are difference scores calculated over the direction of an infant's first response to each trial, the direction of all of an infant's responses within each trial, or the summed time that an infant spends looking in each direction for each trial (Corkum & Moore, 1995; Johnson et al., 1998; Senju & Csibra, 2008). We report the last of these options, as it optimizes sensitivity (by considering multiple looks within a trial), robustness (by weighting looks by their duration), and ecological validity (because aggregating multiple looks reflects the common joint attentional pattern of looking back and forth between social partner and target). Scores for the other two common metrics yielded largely similar results; the one divergent case (Experiment 1, hand clap condition) is noted in the relevant Discussion section.

Reviewing the video recordings, we discovered that infants occasionally were not watching the entity when it turned (average number of trials witnessed: conversation, 3.44; hand clap, 3.84; person silent, 3.56). Thus, only data from trials where the infant viewed the entire event were counted. To compare scores of infants who saw different numbers of trials, we introduced a correction: We divided each infant's difference scores by the number of trials that he or she saw and then multiplied by four to estimate what the score would have been had the infant viewed all four trials. All infants saw at least two of the four trials; there was no difference in the number of trials viewed among the three experimental conditions, $F(2, 72) = 2.55$, $p = ns$.

Results

Preliminary analyses in this and subsequent experiments examined the effects of participant sex and the direction of the entity's first turn, in addition to the experimental condition. There were no main effects or interactions involving these factors in any experiment, so the reported analyses are collapsed over them.

Comparisons to chance. Infants' difference scores in each condition were first compared to chance performance (i.e., zero: equal time looking in each direction; see Figure 2). Infants in the conversation condition ($M = 2.56$, $SD = 3.07$) and hand clap condition ($M = 2.05$, $SD = 4.63$) looked in the indicated direction at levels significantly greater than chance, $t(24) = 4.03$, $p < .001$; $t(24) = 2.22$, $p = .037$ (both two-tailed). Those in the person silent condition did not ($M = -0.20$, $SD = 5.07$), $t(24) < 1$, ns.

Differences between conditions. A one-way analysis of variance (ANOVA) examined the effects of condition (conversation, hand clap, person silent) on infants' difference scores. There was a marginally significant effect of condition, $F(2, 72) = 2.83$, $p = .066$. Planned least significance difference (LSD) comparisons (all two-tailed) revealed that infants in the conversation condition had significantly higher scores than those in the person silent condition, $t(72) = 2.24$, $p = .029$, but did not perform significantly differently from those in the hand clap condition, $t(72) < 1$, $p = ns$. Infants in the hand clap condition scored marginally higher than those in the person silent condition, $t(72) = 1.82$, $p = .073$.

Discussion

Infants in the conversation condition followed the attentional focus of the novel entity, but infants in the person silent condition did not. This result provides a strong replication of the earlier finding (Johnson, 2003; Johnson et al., 2008) that infants follow the attentional focus of a novel entity that has participated in a contingent conversation-like interaction with a person. Further, chance performance in the person silent condition confirms that the novel entity's partially animal-like features and its self-generated behavior (beeping, blinking, turning on its own) were not sufficient cues for attributing agency to it.

Infants in the hand clap condition also followed the entity's attentional focus, indicating that the verbal aspect of the interaction in the conversation condition was not necessary for agent detection. Although this result is consistent with the proposal that infants treat any brief turn-taking contingent interaction as sufficient evidence for an entity's agency, it is also consistent with the hypothesis that the social nature of a contingent interaction contributes to infants' attributions; after all, the hand-clapping game is commonly played between infants and caregivers, and the experimenter attended to the entity in a smiling manner. The full data provide a hint, however, that contingency information, identical in

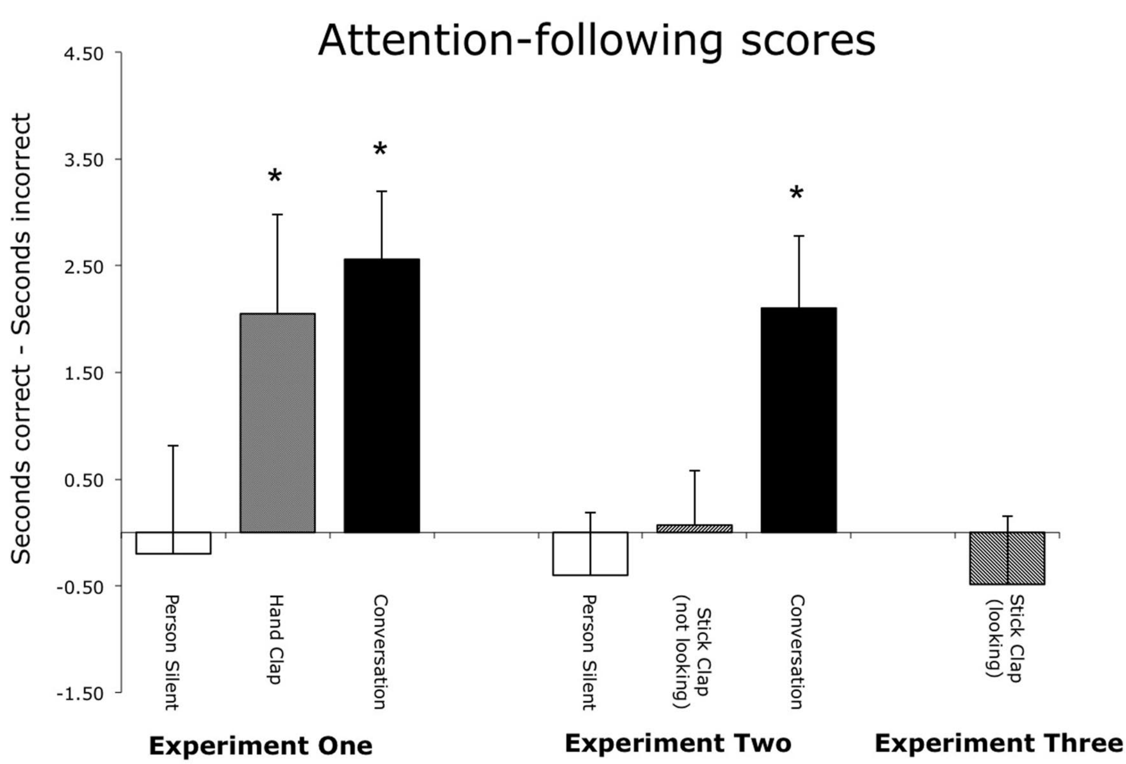

Figure 2. Mean attention-following scores for infants in Experiments 1–3. Error bars indicate standard error of the mean. $N = 25$ in each condition. An asterisk indicates a difference score that was significantly different from chance ($p < .05$).

the conversation and hand clap conditions, was not the sole determinant of infants' agency attributions. On the two alternative ways of calculating difference scores, mentioned in the Scoring section, the hand clap condition did not yield difference scores that were significantly different from the baseline person silent condition.[1] (Note, for all other conditions in all of the experiments, analyses of first looks and total looks yielded exactly the same pattern of findings as those using total looking times that are reported here.) One way to interpret these subtle differences between the hand clap and conversation conditions is that familiar social elements, present in the hand clap game but more salient in the more prototypical conversation, may have aided infants' evaluations of these contingent experimenter/entity interactions.

Experiment 2

Experiment 2 puts to a stronger test the hypothesis that turn-taking contingency, observed between a person and a novel entity, is sufficient for attribution of agency to that entity, irrespective of the actions on which that contingency is based. A new condition maintained exactly the same level of turn-taking contingency between the actions of the novel entity and the experimenter as in the contingent interactions of Experiment 1, but it wholly removed all of the social features of the interaction. The experimenter clapped two wooden sticks together, looked at his hands instead of the entity, and maintained a neutral emotional expression throughout the interaction. If infants treat any turn-taking, contingently acting entity as an intentional agent, we should find that they follow the entity's attention shifts in this condition. This experiment also included two new groups of infants in the conversation and person silent conditions, to further confirm our replication and use of Johnson et al.'s (1998, 2008) method.

Method

Participants. Seventy-five 12- and 13-month-old infants participated in the study (mean age = 53.7 weeks, range = 50.0–58.4), with 25 in each of three conditions (conversation: 14 female; person silent: 14 female; stick clap: 16 female). An additional two infants were run but not included, due to fussiness that required aborting the session.

Procedure. The conversation and person silent conditions were run as in Experiment 1. For the new *stick clap* condition, the experimenter clapped two short wooden sticks together in the same sequence in which he had clapped his hands in Experiment 1's hand clap condition, including pauses for the entity's contingent responses. Throughout the interaction, he maintained a neutral expression and kept his gaze fixed on his hands, never looking directly at the entity.

Scoring. A secondary coder coded 10 infants from each condition, reaching an agreement with the primary coder of .91. As previously, some infants did not see the entity's turn on all trials (average turns witnessed: conversation, 3.48; stick clap, 3.60; person silent, 3.68; no group differences in trials witnessed), $F(2, 72) < 1$, *ns*. The same correction was applied to allow comparison between infants.

Results

Comparisons to chance. The average score for infants in the conversation condition was 2.10 ($SD = 3.39$), which was significantly greater than chance, $t(24) = 3.10$, $p = .005$, two-tailed (see Figure 2). Infants in the stick clap ($M = 0.07$, $SD = 2.56$) and person silent ($M = -0.40$, $SD = 2.93$) conditions did not perform differently from chance, $t(24) < 1$, *ns*, for both.

Differences between conditions. A one-way ANOVA revealed a significant effect of condition (conversation, stick clap, person silent) on infants' responses, $F(2, 72) = 4.99$, $p = .009$. Planned two-tailed LSD comparisons indicated that infants in the conversation condition had significantly higher scores than those in the person silent condition, $t(72) = 2.97$, $p = .004$, and those in the stick clap condition, $t(72) = 2.41$, $p = .018$. Scores for the stick clap and person silent conditions did differ significantly from one another, $t(72) < 1$, $p = ns$.

Discussion

Infants' responses to the conversation and person silent conditions in Experiment 2 matched infants' responses to the same conditions in Experiment 1. We have now replicated Johnson's (2003; Johnson et al., 2008) result twice.

The new result from Experiment 2 is that infants in the stick clap condition did not follow the entity's attentional focus. Because its beeping and blinking were equally contingent upon the experimenter's actions in the conversation, hand clap, and stick clap conditions, we can conclude that the entity's turn-taking contingent response to the experimenter was not sufficient for infants to treat it as an intentional agent. That is, the only difference between the three conditions was the form of the experimenter's actions. Thus, the attribution of intentional agency in the conversation and hand clap conditions was not the result of a process based exclusively on amodal representations of the contingent interaction.

The fact that the experimenter in the stick clap and person silent conditions did not make "eye contact" with the entity may have been a particularly influential manipulation, for either of two reasons. First, it is possible that infants did attribute agency to the entity, but they also observed that the experimenter did not seem very interested in it. This modeled disregard may have led infants away from following its shifting attention. Informal analyses of the video recordings, however, suggest that this was not the case; infants in all conditions were highly interested in the entity and its behavior. Second, as even 10-month-old infants expect people to look at each other while communicating (Beier & Spelke, 2012), the experimenter's lack of visual regard toward the entity may have indicated that the entity was not a likely social partner. Such an account is consistent with our hypothesis that social information informs the detection of agents from contingencies. We test both of these possibilities in Experiment 3.

[1] For the hand clap condition, difference scores based on infants' first responses to the entity's turns ($M = 0.41$, $SD = 1.6$) and on the number of times infants turned on each trial ($M = 0.61$, $SD = 2.4$) were not different from chance, $t(24) = 1.28$ and $t(24) = 1.27$, respectively (both *ns*).

Experiment 3

Experiment 3 was a modified version of the stick clap condition of Experiment 2. As before, the experimenter clapped two sticks together while maintaining a neutral expression, to which the novel entity responded contingently. In this version, the experimenter performed his actions while looking intently at the entity's front end. Infants thus received evidence from the experimenter that the entity and its response were worth their close attention, and they also observed that the experimenter's gaze was consistent with a social interaction. However, the experimenter's actions were not apparently social, and he did not react emotionally to the entity.

Method

Participants. Twenty-five 12- and 13-month-old infants participated in the study (13 female; mean age = 55.6 weeks, range = 50.1–58.5). An additional two infants were run but not included, both due to fussiness.

Procedure. The procedure was identical to the one used in the stick clap condition of Experiment 2, with one exception. During the entire 60-s interaction, the experimenter looked directly at the front end of the novel entity.

Scoring. A secondary coder coded 10 infants and reached an agreement with the primary coder of .92, calculated as before. We again applied a correction to allow comparison between infants who witnessed different numbers of turns (average turns viewed = 3.6).

Results

The average score was not significantly different from chance performance ($M = -0.49$, $SD = 3.19$, $t < 1$, $p = ns$; see Figure 2).

Comparisons among all conditions run. We pooled data across Experiments 1–3 to make comparisons across all of the conditions run (combining the conversation and person silent conditions of Experiment 1 and 2 into two single conditions). A one-way ANOVA with condition—person silent, stick clap (not looking), stick clap (looking), hand clap, conversation—as a between-subjects factor indicated a significant effect of condition, $F(4, 170) = 5.11$, $p = .001$, on infants' responses. A two-tailed Dunnett's test compared each of the contingent interaction conditions against the noncontingent person silent baseline condition; the conversation and hand clap conditions were both significantly different from baseline ($p = .002$ and $p = .034$, respectively), but the two stick clap conditions were not ($p = .99$ for both).

Because our interpretation of these data considers both the presence and the absence of attention-following across conditions, we supplemented the above null hypothesis tests with Bayes factor *t* tests for each comparison against the baseline. Bayes factors (BF) quantify the odds in favor of the null hypothesis (i.e., no difference between conditions) compared to the alternative hypothesis; a $BF < 1$ provides support for the alternative hypothesis, and a $BF > 1$ provides support for the null. Jeffrey–Zellner–Siow Prior (JZS) Bayes factors were computed from the web-applet on Jeffrey Rouder's website (Rouder, Speckman, Sun, Morey, & Iverson, 2009; http://pcl.missouri.edu/bayesfactor). Contrasting the person silent baseline with the conversation ($t = 3.61$, $N = 100$, $BF = .019$) and hand clap ($t = 2.63$, $N = 75$, $BF = .25$) conditions indicates that the evidence favoring the alternative hypotheses is "very strong" and "substantial," respectively (Jeffreys, 1961, p. 432). Contrasting the baseline with the stick clap (not looking) condition ($t = 0.41$, $N = 75$, $BF = 4.99$) and the stick clap (looking) condition ($t = 0.21$, $N = 75$, $BF = 5.29$) indicates that the evidence favoring the null hypothesis is "substantial" in both cases. These Bayes factor analyses thus confirm the pattern of results suggested by traditional frequentist statistical approaches.

Discussion

In Experiment 3, infants saw the novel entity respond contingently to an experimenter who was clearly interested in its response, but they did not subsequently follow its implied attentional shift. The absence of attention following in Experiment 2's stick clap condition was therefore not simply a consequence of the experimenter's apparent disinterest in the entity. Instead, Experiment 3 confirms the conclusion of Experiment 2: Observation of a turn-taking contingent interaction between an entity and a person is not sufficient to lead 12-month-old infants to attribute intentional agency to that entity.

The comparison among the conditions from all three experiments begins to provide insight into what else is needed for intentional attributions to third-party entities at this age. From Experiment 3 we learn that contingent turn taking between a novel entity and a person, plus rapt attention from the person, is not sufficient. Apparently, emotional engagement, or falling under a prototypical social interaction (e.g., conversation, turn-taking hand clapping), or both is also required. We return to this issue in the General Discussion.

Experiment 4

Johnson (2003) presented evidence that infants and adults share an agent detection mechanism that responds to a novel entity's contingent response to its environment. Adult participants who viewed a novel entity respond contingently to an experimenter's speech later described its behavior using psychological terms such as *looking* or *wanting,* but others who saw it act in a noncontingent, nonsocial manner focused more on its mechanical motion. Adults' responses thus indicated the same pattern of intentional agency attribution that Johnson inferred from infants' attention-following responses to comparable displays, suggesting that the same mechanism may be involved.

This is a counterintuitive hypothesis, because adults clearly knew that the novel entity was a mechanical object constructed by the researchers. However, adults often draw conceptually rich, abstract inferences about animated stimuli that they know explicitly have no intrinsic intentional or causal structure (e.g., Heider & Simmel, 1944; Michotte, 1946/1963). Processes of agent representation may guide reasoning about entities on an implicit level, without fully determining one's explicit beliefs about the entity or without being fully determined by one's explicit beliefs.

Because Experiments 2 and 3 have undermined the evidence in infancy for an automatic mechanism that infers agency from amodal representations of third-party contingency, Experiment 4 reexamines whether such a mechanism operates in adulthood. Unlike infants, adults may yet treat any turn-taking contingency between novel entities or between a novel entity and a known agent as sufficient for agent detection. If so, we would conclude that an amodal mechanism is constructed in the course of development, abstracted from experience, and is not in place from the outset. Alternatively, Johnson's conclusions regarding developmental continuity may hold, even if the context-sensitive mechanism involved would be somewhat different from the context-independent contingency detection mechanism she envisioned.

Using the same strategy as in our previous infant studies, we first replicate Johnson's findings with adults with the same conditions she studied (conversation, person silent, and a new entity silent condition). We then introduce new conditions, in which the turn-taking contingency between the novel entity and some other entity's behavior is identical to that in the conversation condition, that vary the nature of the events that constitute the contingency (stick clap and a new novel object condition).

Method

Participants. Eighty-nine adults participated (all fluent in English, between 18 and 35 years of age; 58 female). They were recruited from the Harvard University Psychology Department's study pool. Although demographic information for individual participants was not collected, approximately 72% of study pool participants identified as White; 12% were Asian, 5% were Hispanic, 5% were Black, and 6% were from other backgrounds. Most were undergraduates receiving course credit; others, including university affiliates and area residents, received $5 compensation.

Apparatus. The basic apparatus was the same as in Experiments 1–3, except that the appearance of the novel entity was changed to remove any possible cues for its animacy (see Figure 1). The front end of the entity was made less headlike, and we replaced its brown fur with a semismooth surface made with Crayola Model Magic, painted bright green. The entity retained the same red light on the top of its front end.

Procedure. The presentation of the novel entity and its turning followed the same sequence as in the infant studies, with two exceptions. First, the entity was hidden until the puppeteer raised a screen at the start of the 60-s interaction phase. Second, after the interaction but before the novel entity performed its turns, the experimenter left the testing room (in the infant version, he had crouched behind the caregiver's chair).

Each participant was assigned to one of five conditions. The *conversation* condition (19 participants) was the same as in Experiments 1 and 2. The entity responded contingently with beeps and light flashes to the speech of an experimenter who looked and smiled at it.

In the *entity silent* condition (20 participants), the experimenter spoke to the entity just as in the conversation condition, but the entity did not respond at all. Consequently, there was no turn-taking contingency between the novel entity and the experimenter. This condition was not run with infants in our experiments, but it has been run with both adults and infants in previous studies (Johnson, 2003; Johnson et al., 2007).

The *person silent* condition (16 participants) was the same as in Experiments 1 and 2. The entity's beeping and blinking was not contingent upon anything the experimenter did, as he was looking down at his hands with a neutral expression, doing nothing while the entity acted.

The *stick clap* condition (17 participants) was the same as in Experiment 3. The experimenter looked at the entity with a neutral expression while clapping sticks. It responded with the same contingency as in the conversation condition, but there was no social context.

In the *novel object* condition (17 participants), the experimenter was replaced with a novel object (see Figure 1). The entity responded contingently to the novel object's actions, but this object did not have a face or an obvious front that could specify direction of gaze or emotional reactions. Neither the original novel entity's nor this new novel object's behaviors were verbal or fell under any familiar schema of interaction between known agents. The novel object was constructed from three pink foam noodles, about four feet tall, wrapped in a string of Christmas lights. It was approximately the same size and shape as the kneeling experimenter that it replaced. The lights blinked in the same sequence as the stick claps in the stick clap condition. When this condition was run, the experimenter left the testing room prior to the interaction between the novel entities and reentered the room between the interaction and turning phase to remove the novel object.

Following the interaction and turning sequence, the experimenter returned to the testing room and escorted the participant to a new room, where he or she completed a short written survey. The survey included two questions designed to elicit verbal descriptions of the entity's turning sequence. One, following Johnson (2003) was, "Why did the thing on the stage turn?" To elicit more language, we also asked, "What happened after the experimenter left the room?" Each question was printed at the top of a separate page in order to allow open-ended responses, and they were always asked in the same order.

Scoring. A primary coder, blind to condition, scored responses to the questions, following Johnson's (2003) strict criteria for psychological attributions. Three general rules guided scoring. First, language that included an explicitly mental characterization of the entity or its reasons for acting as it did counted as evidence for a psychological attribution. The most common descriptions in this category characterized the novel entity as "looking," "talking," or "wanting." Second, language that invoked merely animate terms to describe the entity, such as "turned its head," did not count as evidence for psychological attribution. Third, language whose proper scoring was unclear was not counted as evidence for psychological attribution. Most ambiguous responses were of one of two types. First, responses such as "pointing at one of the lights" could describe either the physical orientation of the entity or a communicative act. Second, some responses indicated that participants knew that the entity's motion was intended to influence them in a particular way, but their descriptions left it unclear whether they were describing an intention of the entity or of the experimenter who had designed the study. Sample response segments indicating intentional and nonintentional attribution for each question, as well as ambiguous responses, are presented in Table 1.

Participants whose responses to either of the two questions indicated a psychological attribution were scored as attributors on a dichotomous outcome variable. A secondary coder, blind to condition, rescored all responses. Agreement between coders on classification of each participant as an attributor or nonattributor was perfect.

Table 1
Sample Questions and Answers for Experiment 4

Question	Intentional	Not intentional	Ambiguous
Why did the thing on the stage turn?	"To see the light"	"Because there was someone operating it from behind, perhaps mechanically"	"To make me look at the lights"
What happened after the experimenter left the room?	"The little creature started talking (beeping) to me and moved around the stage a bit"	"The thing on the stage started turning after certain patterns of blinks/beeps"	"The blob would turn toward the left or the right, pointing at one of the lights that went on"

Results

The novel entity's behavior was sometimes described using rich mentalistic language. Participants invoked a wide variety of types of mental states, often integrated in a single description. For example, asked why the thing on the stage turned, one participant replied, "I'm not sure why it turned; it seemed to be looking at the two lights on the side. First it would beep and signal with the light before turning as if in explanation, but I clearly couldn't understand what it meant." Another replied, "Maybe it turned because it wanted to talk to the lights." Across all descriptions in which intentional agency was attributed to the novel entity, participants described it as looking at or seeing something, talking or communicating, wanting something, directing attention or indicating something, looking for something or somebody, and flirting or having a friend.

The number of participants responding with intentional descriptions for each condition was as follows: conversation, 11 of 19; entity silent, 6 of 20; person silent, 3 of 16; stick clap, 2 of 17; novel object, 2 of 17 (see Figure 3). A Pearson's chi-square test, performed on all five conditions, revealed a significant effect of condition, $\chi^2(4) = 13.86$, $p = .008$.

A set of Fisher's exact tests, using Overall's continuity correction for 2 × 2 tables (Overall, 1980; Overall, Rhoades, & Starbuck, 1987), confirmed replication of Johnson's (2003) findings

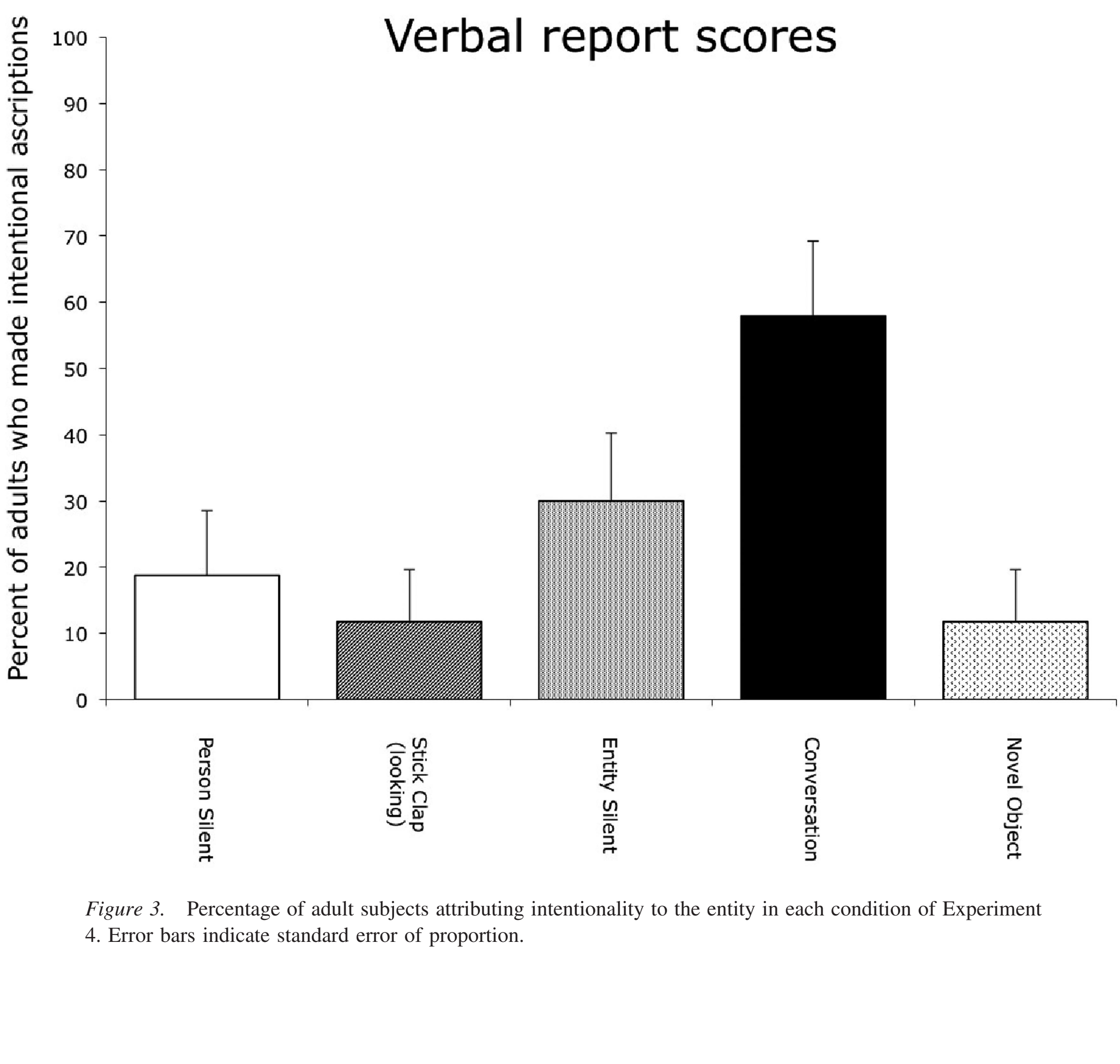

Figure 3. Percentage of adult subjects attributing intentionality to the entity in each condition of Experiment 4. Error bars indicate standard error of proportion.

for the conversation, entity silent, and person silent conditions. Participants described the novel entity using psychological terms significantly more often in the conversation condition than the person silent (p = .01, one-tailed) or entity silent (p = .043, one-tailed) conditions. The person silent and entity silent conditions did not differ from one another (p = *ns*, one-tailed).

Finally, the same analyses were performed on the two new conditions, using the person silent condition as a baseline measure of participants' tendencies to describe the novel entity in psychological terms. Participants in the stick clap and novel object conditions did not differ from baseline (p = *ns*, two-tailed, for both). Participants in both groups were also less likely to use psychological terms than those in the conversation condition (p = .002, two-tailed, for both).

Discussion

Experiment 4 replicates Johnson's (2003) finding that adult participants use psychological language to describe and account for a novel entity's behavior under the same conditions that infants follow an attentional shift of that novel entity. That is, they do so if they have previously seen a turn-taking "conversation" between that entity and an experimenter but not if they saw the experimenter address the entity with no response or if they saw the entity beep and flash with no response from the experimenter.

Experiment 4 also extends the shared pattern of results between infants and adults to the stick clap condition of Experiment 3. Here, adults failed to use psychological language after witnessing a novel entity respond in a turn-taking manner to the experimenter's stick claps, even though their interaction was fully contingent and the experimenter gazed attentively at the entity throughout. Just as for infants, the nature of a turn-taking contingent interaction influences whether adults take it as evidence that the interacting entities are intentional agents.

Adults' failure to use psychological language in the new novel object condition provides further evidence that turn-taking contingency is not sufficient on its own for observers to treat the participating entities as intentional agents. It also bears on the question of exactly when during processing the nature or context of a contingent interaction is taken into account. It is possible that turn-taking contingency does trigger the attribution of intentionality automatically but that aspects of the experimenter's behavior (e.g., stick clapping vs. natural language or neutral vs. warm emotions) subsequently led participants to overturn that attribution. The novel object condition, however, refutes this possibility: With no expectations concerning typical interactions between two novel agents, participants would have had no reason to overturn any initial attributions of intentional agency. Future work should explore a similar condition with infants. Because infants are still learning about how agents interact in different circumstances, 12-month-olds in the stick clap conditions are unlikely to have reversed initial intentionality attributions based on strong expectations about typical agent–agent interactions, especially as adults do not.

Adults undoubtedly maintained explicit beliefs about the entity's true inanimate nature throughout the study. That they sometimes made intentional attributions to it has two possible explanations. One is that offered by Johnson (2003); namely, that infants' and adults' common patterns of intentionality attribution, across a range of conditions, reveal the operation of an automatic mechanism for agent detection present in both infancy and adulthood. Given appropriate input, this mechanism is hypothesized to produce an implicit representation of a novel entity as an intentional agent. Despite adults' explicit knowledge that it was not a real agent, this implicit representation may have influenced adults' word choices by making it feel simpler and more natural to describe the mechanism's behavior as if it were an agent.

A second interpretation is that adults' verbal descriptions reflect fully explicit representations and reasoning. That is, adults may have attempted to figure out how the experimenter wanted them to respond. Such an account, however, would require counterintuitive reasoning by participants. In both the conversation and entity silent conditions the experimenter acted as if the entity was his social partner and an intentional agent, yet participants' psychological descriptions were significantly more prevalent in the conversation condition. Remember, though, that participants saw only one condition each and therefore were not privy to the contrast in the entity's responsiveness between these two conditions. For the explicit reasoning account to hold, participants in the entity silent condition must have recognized the experimenter's pretense yet refrained from joining it because the entity did not appear to respond. Those in the conversation condition must have chosen to join the experimenter's pretense while disregarding all of the other aspects of the entity's appearance and behavior that were unlike any other known agent. Participants must have spontaneously recognized that, in the context of the experiment, their own expectations for how agents respond to other people's actions should trump the experimenter's modeled pretense.

The central issue is therefore not whether adult participants decided to pretend that the entity was an agent, but whether their decision to do so was based on explicit reasoning about agents' properties or whether it was influenced by an implicit representation of the novel entity as an agent. Future studies could distinguish between these two interpretations by using nonverbal techniques that do not encourage reflection, such as measures of reflexive orienting following attentional cueing (e.g., Friesen & Kingstone, 1998).

General Discussion

Even when a novel entity looks nothing like a person or any other familiar agent, different aspects of its behavior may provide evidence for its intentional agency. Many researchers have proposed that infants utilize a cognitive mechanism for agent detection that takes as input abstract, amodal representations of an entity's contingent responses to events in its environment (Csibra, 2010; Gergely, 2010; Johnson, 2003). The present studies reveal that this proposal is incorrect, at least for third-party observations of contingent interactions. Neither infants nor adults considered a novel entity's participation in a contingent turn-taking interaction with another person to be sufficient evidence for its status as an intentional agent.

Experiments 1 and 2 established the robustness of Johnson's (2003; Johnson et al., 2008) findings that 12-month-old infants follow an inferred shift of attention of a faceless novel entity if the entity has previously beeped and flashed a light in apparent conversation with an experimenter who talked to it, looked at it, and smiled at its responses. Additionally, infants failed to respond similarly if the entity had previously shown exactly the same pattern of behavior in the presence of a nonresponsive experimenter.

The present studies also introduced several new conditions to investigate the range of contingent interactions that infants take to be evidence for an entity's agency. These conditions maintained exactly the same contingency between the entity and experimenter as in the conversation condition, but they varied the experimenter's behavior within their interaction. In the hand clap condition (Experiment 1), after the entity had responded contingently to an experimenter who clapped his hands playfully while smiling warmly toward it, infants followed the entity's subsequent attention shift. In the two stick clap conditions (Experiments 2 and 3), however, after the entity had responded contingently to an experimenter who clapped two sticks together with neutral emotional affect, infants did not follow its attention shift.

Infants' nonresponses in the stick clap conditions demonstrate that the attribution of intentional agency to a novel entity does not proceed solely from amodal representations of turn-taking contingency obtained through third-party observations of an entity's response to its environment. Moreover, a comparison of responses across all of the conditions tested can guide future investigations of the features that do lead infants to attribute intentional agency to a contingently acting entity. Either the nature of the actions that constituted the contingency (e.g., the experimenter's speech, hand claps, or stick claps) or some other aspect of the context in which it was expressed (e.g., the experimenter's positive emotional displays toward the entity vs. his attentive but emotionally neutral displays) clearly influenced infants' intentional attributions.

Experiment 4 further demonstrates continuity across development in the information used to determine whether to treat a novel entity as an intentional agent. Adult participants viewed a range of contingent interactions between the novel entity and experimenter, many of which were similar to those that infants had viewed. When the entity had responded contingently to the experimenter's conversation, participants spontaneously described its subsequent rotations as "looking" or "showing," but when it had responded contingently to his stick clapping, or to the light flashes of a second novel entity, they used primarily inanimate mechanical terms in their descriptions. For adults, like infants, the contingency of the entity's responses was not sufficient on its own to encourage them to view it as an intentional agent.

Given infants' and adults' similar patterns of responding, these studies raise the possibility that they share a mechanism for detecting agents from observed contingent interactions (Johnson, 2003). The studies with infants establish the existence, early in development, of a cognitive mechanism that automatically produces a representation of an entity as an intentional agent from certain types of contingent interactions, without the need for explicit reflection. This mechanism may continue to operate in adulthood, even in the face of explicit knowledge about an entity's true inanimate nature (cf. Heider & Simmel, 1944). Future studies can address whether this account is correct or whether adults' responses are better seen as the outcome of explicit reasoning about the descriptions the experimenter wanted them to provide.

On the Mechanism of Agent Detection

These findings reveal that an entity's contingent responses to its environment do not wholly determine whether an observer will attribute agency to it. Yet, there are several good reasons to think that these responses still play a role in observers' evaluations. In an earlier study, 13-month-old infants did not interpret a novel entity's behavior as agentive if it had previously been nonresponsive when an experimenter addressed it communicatively (Johnson et al., 2007). Similarly, another prior study demonstrated that addressing a novel entity with a full range of social and communicative behaviors does not lead 15-month-old infants to address it communicatively (Johnson et al., 2001). Finally, in both the present Experiment 4 and an earlier study (Johnson, 2003), adults who watched an experimenter speak to a nonresponsive entity were significantly less likely to describe it as an intentional agent than if it had responded to the experimenter's speech contingently. All of these results provide compelling evidence that an entity's contingent responses influence the determination of its status as an intentional agent and that social modeling is not sufficient for agent detection on its own.

The question then arises of just why certain types of contingent interactions are seen as better evidence for an entity's agency than others. It appears that observers attempt to match their observations of an entity's behavior with a representation of familiar agentive behavior. However, the present results are consistent with at least two different hypotheses regarding the format of this representation. It may be that infants attempt to assimilate their observations of a contingent interaction to a specific familiar schema, in which two agents interact with one another in a particular manner. On this account, infants would have recognized the familiar social interactions of the conversation and hand clap conditions and understood that an intentional agent typically fills the role played by the novel entity in these schematic interactions. This hypothesis predicts that infants would attribute agency to an entity participating in other familiar interactions for which they have a schema (e.g., peekaboo games or handing toys back and forth), and would be less likely to do so if the conversation or hand clap conditions were made less like the relevant schemas (e.g., by removing mutual eye gaze or positive affect).

Alternatively, infants may attempt to interpret a contingent interaction in a more sophisticated way, evaluating whether it shares the more general properties of a successful social interaction. These general properties would include the common behavioral correlates of a successful interaction but may also include more abstract notions of the mental experiences that motivate and underlie them. On this account, the experimenter's behaviors in the conversation and hand clap conditions, as well as his continued satisfaction in the entity's contingent responses, could have led infants to interpret both his and the entity's behaviors as efforts to engage one another socially. The attribution of intentional agency to the entity would be a consequence of this interpretation. This hypothesis assumes that specific behaviors by the experimenter matter less than the overall impression of a satisfying interaction; it therefore predicts that infants would attribute agency to the entity in a modified stick clap condition, so long as other features indicated that the experimenter was trying to establish a social interaction with it (e.g., direct eye gaze, emotional reactions to its responses).

This latter hypothesis raises the possibility that, in the course of evaluating the intentional agency of the novel entity, infants attribute specific social goals to it, such as communicating or playing with the experimenter. That is, the agent detection process may depend upon seeing an entity's behavior as goal directed. Such an account has many parallels with the well-documented teleological attribution system by which infants infer and reason about the goal directedness of both familiar agents and novel entities. In this inferential system, an entity in motion is seen as goal directed if its actions are the rational means for achieving its goal, the end state of the motion event (Gergely & Csibra, 2003). In cases where the end state is not salient, infants will view an action as goal directed if the end state is highlighted via an action effect (Biro & Leslie, 2007; Jovanovic et al., 2007; Király, Jovanovic, Prinz, Aschersleben, & Gergely, 2003). By rough analogy, the social context provided by the experimenter's behaviors in the conversation and hand clap conditions may have highlighted a social goal toward which the novel entity's beeping and blinking might be aimed: engaging the experimenter in a social interaction. By identifying this social goal, infants could then recognize that the entity's contingent behavior was a rational means of accomplishing it.

Both of the above hypotheses assume that the key distinction between conditions that did and did not lead to agent detection is whether the contingent interaction appeared to be a social interaction. The question of exactly what constitutes a social interaction, for the purpose of agent detection, remains open at this time. The answer will largely depend upon which hypothesis is correct; moreover, it will also depend upon the specific knowledge of the individual observer who is evaluating an entity.

Because infants must match their observations of specific actions by the experimenter to a stored representation of familiar social behavior, it seems likely that information gleaned from their experiences of the social world will inform their evaluations. The present studies, however, were not designed to address the relative contributions of innate versus learned knowledge to infants' attributions. By 12 months of age, the schematic or generalized social knowledge that infants in the present study used to evaluate a novel entity's contingent behavior may derive from a combination of innate expectations for the behaviors of agents, infants' own experiences of interacting with agents, and their observations of interactions between other agents.

Implications for Social Cognitive Development

These results make several contributions to a broader account of social cognitive development. First, they establish yet another case where the mechanism that apparently drives an infant's own responses during an interaction is not available to drive the infant's interpretation of an agent's interactions with others. As discussed in the introduction, several studies jointly provide initial evidence that an amodal representation of an entity's contingent behavior within a directly experienced interaction is sufficient for attributing intentional agency to the entity (e.g., Deligianni et al., 2011; Johnson et al., 1998; Téglás et al., 2011). The present studies, in contrast, demonstrate that infants are extraordinarily sensitive to the contextual aspects of contingencies established between a novel entity and another person. The difference in input conditions for these two agent detection processes suggests that distinct cognitive mechanisms are involved.

Similar disjunctions between an intersubjective, second-person social understanding and a more removed, third-party understanding have been demonstrated in other areas of early social cognition, including detecting social gaze (Beier & Spelke, 2012), knowing what another person has experienced (Moll et al., 2007; Moll & Tomasello, 2007), and learning words and actions from a speaker (Floor & Akhtar, 2006; Herold & Akhtar, 2008; Király et al., 2004). Although these cases vary considerably in the complexity of the inferences involved, in each one infants appear to display an earlier understanding of a social event when it occurs in the context of a direct interaction. The present studies may follow this pattern as well: Although younger ages have not been tested, the earliest demonstration of agency attribution from third-party observations of contingent interactions is 12 months. A recent study suggests that 8-month-old infants may attribute agency within direct contingent interactions (Deligianni et al., 2011).

One possible interpretation of this developmental trend draws on consideration of the evolutionary and ontogenetic origins of the mechanisms involved. It may be that the mechanisms that initially drive infants' responses within a social interaction have been shaped by natural selection to assist infants in certain key social functions—for instance, detecting eye gaze or learning from a teacher (Csibra & Gergely, 2006; Farroni, Csibra, Simion, & Johnson, 2002; Watson, 1972). Yet, these mechanisms may not be available for analyzing the same social interactions when they occur between other people. For this, conceptual development may be necessary. Once an infant has built up a more general understanding of interactions between people, the concepts derived from this process will likely also be applied to the infant's own interactions, supporting a much richer understanding than was originally in place.

The finding that two different mechanisms attribute agency, one following directly experienced contingent interactions and the other following observed contingent interactions, bears upon a current debate regarding the nature of the agency representations that these mechanisms produce. Some theorists argue that agency representations are richly integrated, pulling together attributions of different intentional mental states and expectations for behavior based upon them (Johnson, 2003). Other theorists hold that infants' representations of communicative partners are distinct from their representations of goal-directed agents (Gergely, 2010). One of the central points of contention between these two positions is whether, when infants follow the attentional focus of a novel, contingently responding entity, they do so because they have construed it as an integrated intentional agent or, more limitedly, as a communicative partner. Prior to the present results, theorists of the first type could point to a collection of studies indicating that infants also reason about different manifestations of a contingent entity's agency, such as the placement of its perceptual organs and the goal directedness of its motion (Johnson et al., 2007, 2008; Shimizu & Johnson, 2004). Because these studies were conducted using third-party observations of an entity's contingency, however, our finding that the mechanism evaluating contingency in this instance may be distinct from the one evaluating direct contingencies means that these results do not necessarily inform our understanding of the inferences that infants make when faced with an entity that is contingent upon their own actions. The present results therefore highlight the need for further studies that investigate the range of inferences infants make about directly contingent entities, including expectations for their goal-directed behavior.

Finally, the present findings emphasize that infants' early social cognitive understanding is about truly social phenomena. In addition to requiring the imputation of intentional mental states to an individual agent, the present studies require that 12-month-old infants reason about a social interaction that occurs between two agents. As discussed earlier, this reasoning may even involve notions of social goals that one agent has toward the other. These findings are therefore concordant with infants' other achievements in social understanding, as they come to appreciate both affiliative and antagonistic encounters as interactions of minds rather than bodies.

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