Early understandings of the link between agents and order

George E. Newman[a,1], Frank C. Keil[b], Valerie A. Kuhlmeier[c], and Karen Wynn[b]

[a]School of Management, Yale University, New Haven, CT 06520; [b]Department of Psychology, Yale University, New Haven, CT 06520; and [c]Department of Psychology, Queen's University, Kingston, ON, Canada K7L 3N6

Edited by Susan E. Carey, Harvard University, Cambridge, MA, and approved August 25, 2010 (received for review December 7, 2009)

The world around us presents two fundamentally different forms of patterns: those that appear random and those that appear ordered. As adults we appreciate that these two types of patterns tend to arise from very different sorts of causal processes. Typically, we expect that, whereas agents can increase the orderliness of a system, inanimate objects can cause only increased disorder. Thus, one major division in the world of causal entities is between those that are capable of "reversing local entropy" and those that are not. In the present studies we find that sensitivity to the unique link between agents and order emerges quite early in development. Results from three experiments suggest that by 12 mo of age infants associate agents with the creation of order and inanimate objects with the creation of disorder. Such expectations appear to be robust into children's preschool years and are hypothesized to result from a more general understanding that agents causally intervene on the world in fundamentally different ways from inanimate objects.

cognitive development | agency | entropy | infancy | childhood

Although the Second Law of Thermodynamics is often understood as stating that isolated systems tend to move from order to disorder in a manner that increases entropy, we frequently encounter cases where an external entity can take a system from relative disorder to order. Most of the time, the entity is an "agent," meaning a goal-directed actor, and very often that agent is thought of as having intentions to bring order to the system—for example, a parent cleans up a child's room by stacking items of like kind in different piles.

As adults, however, we do not typically see inanimate objects as capable of having such effects. It is highly unlikely that a rolling ball or falling stone could increase the orderliness of a system. We would be surprised to see such an event because we normally assume that order arises from the actions of agents, not inanimate objects. There are of course exceptions in which orderly arrangements do arise from inanimate processes (e.g., crystal growth or the ordering of pebbles on a beach tideline). However, such phenomena often reflect the unique interaction between a given set of materials and a specific natural process. In contrast, agents (such as people) are capable of creating many different types of order using a near-infinite combination of materials. Thus, as adults, we appreciate that one major division in the world of causal entities is between those that are generally capable of "reversing local entropy" and those that are not.

It might seem that the ability to recognize the unique link between agents and order would be late emerging in development. Components of this knowledge, however, have very early origins. Some forms of order, such as symmetry or statistical regularities, are detected in infancy (1–5). Moreover, there is an extensive developmental literature demonstrating that even infants see agents as different from inanimate objects and that they expect these two kinds of objects to interact differently with the environment (6–13). Finally, infants and young children seem to recognize that there is an "arrow of time" in which systems become more disorderly over time (14–16). Therefore, even though children may be unable to articulate the principles that causally link agents to the creation of order, they may nonetheless be sensitive to such a pattern and how it is distinct from events involving inanimate objects.

Experiment 1

To examine whether children appreciate that agents are unique in their ability to create order, our first experiment presented 40 children (aged 3–6 y) with scenarios involving either an agent (a person) or an inanimate force (the wind). Children were presented with a drawing of a room and were told, "This is a picture of Billy's room. One day, Billy went outside to play and this is how things looked before he left." Half of the children were then told that while Billy was outside his older sister (Julie) went into his room and changed his things (agent condition), and the other half were told that the wind blew strongly through the window and changed his things (Inanimate condition). Children were then presented with a pair of test cards (Fig. 1). One card depicted an ordered arrangement of objects, and other card depicted the same objects in a disordered array.* The children were then asked, "Which one of these piles looks most like Julie (the wind) changed it?" This procedure was repeated for six pairs of arrangements, and responses were classified as either choosing the ordered arrangement (coded as a "1") or choosing the disordered arrangement (coded as a "–1"), which we then summed across participants to produce a score that could range from –6 to 6.

Results and Discussion. Children reported that the person was significantly more likely to make the ordered arrangement [mean (M) = 1.42, SE = 0.89] than was the wind [(M = –4.43, SE = 0.41), $F(1, 38) = 37.95$, $P < 0.001$, $\eta_p^2 = 0.50$]. This pattern was robust both for 5- to 6-y-old children [(Ms = 1.3 and –5.6, respectively; $F(1, 18) = 17.38$, $P = 0.001$, $\eta_p^2 = 0.49$; Mann-Whitney test: $z = 3.01$, $P = 0.004$)] and for 3- to 4-y-old children [(Ms = 1.6 and –3.4, respectively; $F(1, 18) = 31.35$, $P < 0.001$, $\eta_p^2 = 0.64$; Mann-Whitney test: $z = 3.54$, $P < 0.001$)]. Overall, children were reliably more likely to say that the wind made the disordered arrangement (88% of responses) than the ordered arrangement (12% of responses). In contrast, they said that the person could make either the ordered arrangement (62% of responses) or the disordered arrangement (38% of responses).

Author contributions: G.E.N., F.C.K., V.A.K., and K.W. designed research; G.E.N. and V.A.K. performed research; G.E.N. and V.A.K. analyzed data; and G.E.N., F.C.K., V.A.K., and K.W. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

[1]To whom correspondence should be addressed. E-mail: george.newman@yale.edu.

This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.0914056107/-/DCSupplemental.

*In this study, we explored one readily identifiable notion of order: grouping along Gestalt principles of proximity and similarity. To create the ordered arrangements, the objects were separated into two different piles that were organized along a different perceptual dimension. These included grouping by color (two different arrangements), grouping by shape (two different arrangements), grouping by color and shape, and a neatly organized spatial arrangement. The disordered arrangements were not created in any systematic way. All stimuli were presented as cards (color images on poster board). The order in which each item-pair was presented was counterbalanced across participants.

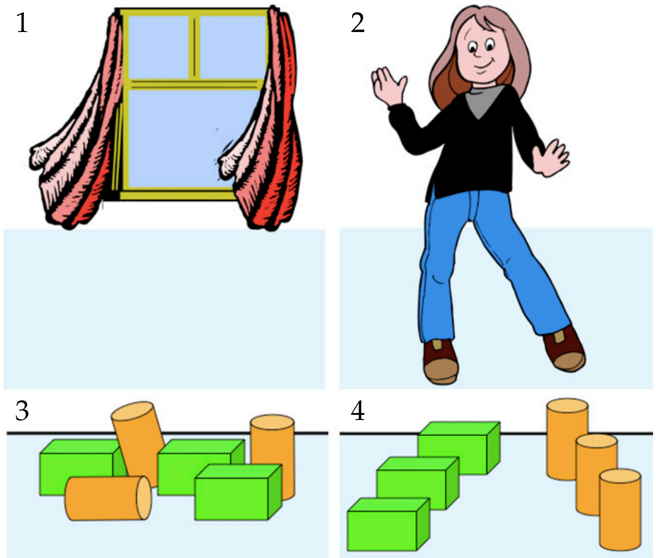

Fig. 1. Sample stimuli presented to children in experiment 1 (1). Picture of the open window (2). Picture of the agent (the "older sister") (3). Example of a "disordered" arrangement (4). Example of a matched "ordered" arrangement.

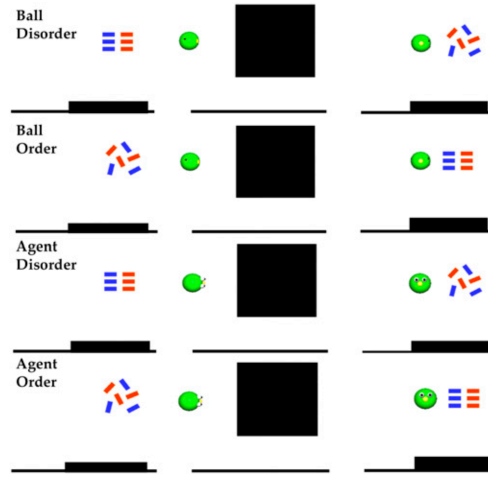

Fig. 2. Depiction of the events presented to infants in experiment 2. These events are presented as a sequence of static frames, with time increasing toward the right. The top two rows show the ball condition in which the ball appeared to change an ordered arrangement of blocks into a disordered pile (disordering event) and a disordered pile into an ordered arrangement (ordering event). The bottom two rows show the same events involving the agent.

Interestingly, however, children were often unable to articulate the basis for their response. In fact, the most common justification was simply to redescribe the visual array. For example, a younger child (age 3 y 8 mo) said of the person, "She made it like that because it was beautiful." These strong preschool intuitions accompanied by an inability to explain them suggested that perhaps even younger, nonverbal populations may be sensitive to these same causal patterns. We examined this possibility in two additional studies.

Experiment 2

In experiment 2, we tested 48 infants of two different ages: 12-mo-olds and 7-mo-olds. Infants in both age groups were exposed to short, computer-animated movies involving either a computer-animated ball (ball condition) or an agent (agent condition). The ball and agent were as similar in appearance as possible (see Fig. 2).

A large literature within developmental psychology has examined what factors lead infants and children to infer that a given entity is animate. In this experiment, we exploited two key cues: Spots on the ball were rearranged to form a face for the agent (17). In addition, the agent moved in a self-propelled manner (18) with its eyes facing the direction of motion whereas the ball rolled across the screen.

At the beginning of the experiment, infants were first shown a movie (played only once) in which the entity (either the ball or the agent, depending on the condition) moved back and forth across the computer screen. Infants were then exposed to two different types of test events: ordering events and disordering events. In the ordering event, it appeared as if the ball or the agent changed a disordered array of blocks into an ordered arrangement. Infants first saw a disordered pile of blocks. An opaque barrier then moved in front of the blocks. Then, the entity appeared from off screen and moved behind the opaque barrier. Both the ball and the agent were in motion when they entered the screen. After a brief pause, the barrier dropped to reveal the blocks in an ordered arrangement (separated by color and organized into two vertical rows). In the disordering event, infants saw an identical sequence of events, but the beginning and end-states of the block arrays were reversed. Therefore, this event appeared as if the entity changed the ordered arrangement of blocks into a disordered array (Movies S1, S2, S3, and S4).

Infants in the ball and agent conditions were shown three pairs of the ordering and disordering test events (with presentation order counterbalanced). For each test event, the amount of time that infants spent looking at the outcome displays was recorded. It is well established that infants look longer at outcomes that they find novel or unexpected (e.g., refs. 19–22). Therefore, we predicted that infants observed in the ball condition would look longer at a ball creating order than at a ball creating disorder. In contrast, we predicted that infants in the agent condition would look equally long at the agent creating order and the agent creating disorder because both outcomes are consistent with actions that agents are capable of completing.

Results and Discussion. The results from the experiment are presented in Fig. 3. As predicted, 12-mo-old infants in the ball condition looked reliably longer when the ball appeared to create order (M = 8.89 s, SE = 1.44) compared with when the ball appeared to create disorder [(M = 6.06 s, SE = 0.90), $F(1, 11) = 13.47$, $P = 0.004$, $\eta_p^2 = 0.55$; Wilcoxon test: $z = 3.06$, $P = 0.002$]. In contrast, infants in the agent condition looked equally long at the ordering (M = 8.45 s, SE = 1.43) and disordering events [(M = 8.8 s, SE = 1.55), $F < 1$, $P = 0.79$; Wilcoxon test: $z = 0.31$, $P = 0.75$]. A mixed-model ANOVA with entity type (ball vs. agent) as a between-subjects factor and test event type (ordering vs. disordering) as a within-subject factor confirmed that the interaction between entity type and test event type was statistically significant [$F(1,22) = 4.28$, $P = 0.05$, $\eta_p^2 = 0.16$].[†] Nonparametric analyses of the data revealed a similar pattern: 12 of 12 infants in the ball condition looked longer at the ordering events, whereas 7 of 12 infants in the agent condition looked longer at the ordering events ($P = 0.037$ via a two-tailed Fisher's exact test).

Seven-month-old infants, however, did not show the same looking-time pattern. Seven-month-old infants in the ball condition looked equally long at the ordering (M = 8.97 s, SE = 1.61) and disordering events [(M = 10.28 s, SE = 1.71), $F(1, 11) = 2.07$,

[†]Further analyses indicated that this effect was comparable across the three trial pairs, and when we included trial pair (1–3) and presentation order as additional factors, the primary interaction of condition and outcome remained significant [$F(1,13) = 5.84$, $P = 0.033$, $\eta_p^2 = 0.31$]. However, there was no main effect or interaction with either trial pair or presentation order.

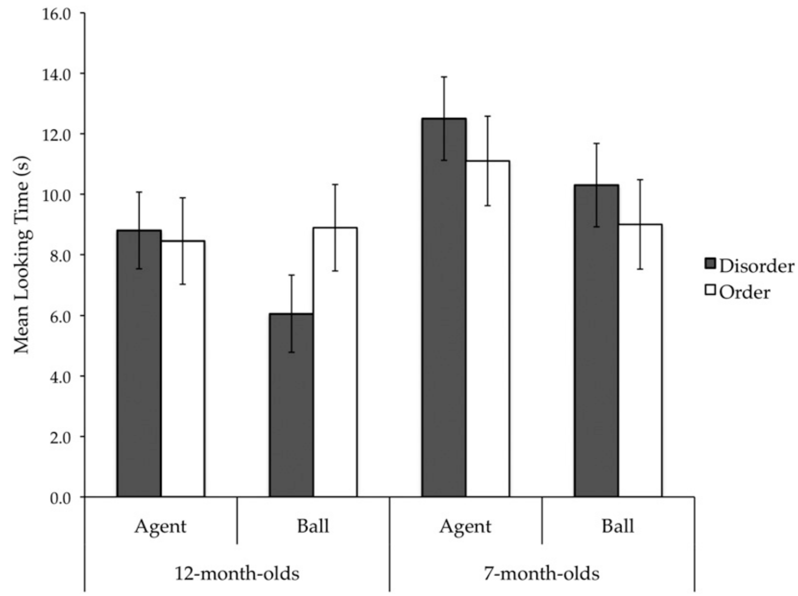

Fig. 3. Mean time (in seconds) spent looking at the ordering and disordering test events in the ball and agent conditions of experiment 2 (±SE).

P = 0.18; Wilcoxon test: z = 1.18, P = 0.24]. Seven-month-old infants in the agent condition also looked equally long at the ordering (M = 11.10 s, SE = 1.11) and disordering events [(M = 12.47 s, SE = 1.23), $F(1, 11) = 0.77$, P = 0.40; Wilcoxon test: z = 0.86, P = 0.39]. Overall, 5 of 12 infants in the ball condition looked longer at the ordering events, and 4 of 12 infants in the agent condition looked longer at the ordering events.

Results from experiment 2 suggested that, by at least 12 mo of age, infants differentiate between inanimate objects and agents when observing changes in perceived order. Twelve-month-old infants responded to an inanimate ball creating order as more unexpected than a ball creating disorder. However, when they viewed identical events involving an agent, they did not respond differently to the ordered and disordered outcomes.

The difference between 12-mo-old and younger infants tentatively suggests that this particular set of expectations is acquired sometime during the second half-year of life. However, the building blocks for this knowledge are likely present much earlier in development. For example, within the first 3–9 mo of life, infants readily distinguish agents from inanimate objects, and this distinction provides an important conceptual framework for later learning (23, 24). Thus, the 7-mo-old infants' looking-time pattern in experiment 2 is probably not due to a failure to appreciate the difference between agents and inanimate objects; nor does it stem from a failure to notice the difference between order and disorder (see ref. 15). Rather, it may be that, by 7 mo of age, infants have not yet detected the relationship between these two different domains of knowledge.

Experiment 3

The previous study suggested that, by as early as 12 mo of age, infants appreciate that inanimate objects cannot create order. The goal of experiment 3 was twofold: First, we wanted to investigate the robustness of this expectation for inanimate objects. Second, given the null difference in looking time for the agent, we were interested in whether infants of this age appreciate that agents may have the disposition to create either order or disorder.

This study tested a new group of 52 12-mo-old infants. Instead of computer animations, however, infants in this experiment were exposed to brief video sequences involving real objects. Half of the infants were exposed to videos that featured an inanimate object (a claw-like stick), and the other half of the infants were exposed to videos that featured an agent (a human hand). At the beginning of the experiment, we also manipulated whether infants were familiarized with video sequences depicting the creation of order or video sequences depicting the creation of disorder. These factors were crossed to produce four experimental conditions in a 2 (entity: claw vs. hand) × 2 (familiarization: ordering vs. disordering) between-subjects design.

Infants in the inanimate claw conditions were presented with ordering and disordering test events that were similar to experiment 2 (see Fig. 4). However, preceding these displays we presented infants with one of two different types of familiarization events. The purpose of these familiarization events was to repeatedly expose infants to what appeared to be either an inanimate object creating order or an inanimate object creating disorder. Therefore, infants in one condition (claw-ordering familiarization) were exposed with "ordering" familiarization events in which it appeared as if the inanimate claw changed a disordered pile of blocks into an ordered arrangement. In contrast, infants in the other claw condition (claw-disordering familiarization) were exposed to "disordering" familiarization events in which it appeared as if the same claw changed an ordered arrangement of blocks into a disordered pile.[‡]

After the familiarization events were presented three times, infants in both conditions were presented with two alternating test events in which the same inanimate claw appeared to create order (ordering test event) and to create disorder (disordering test event) using a new set of blocks (shapes and colors different from those in the familiarization trials). Our logic was that, if infants have the robust expectation that inanimate objects cannot create order, then despite repeated exposures to an inanimate object appearing to create order (claw-ordering familiarization), infants should nonetheless still find the claw creating order to be more unexpected than the claw creating disorder. Therefore, we predicted that, following both types of familiarization events,

[‡]In both the ordering and disordering events, the identical video footage was used. We simply spliced the movie at a point at which the blocks were covered by the barrier (and no other objects were present on screen). This equated the two events for their total duration, the length of time that the claw or hand was on screen, the arrangements of blocks, etc. Please see *Materials and Methods* for a more detailed reporting of the procedure. In addition, all stimuli presented in this study are available in SI Movies S5, S6, S7, S8, S9, S10, S11, and S12.

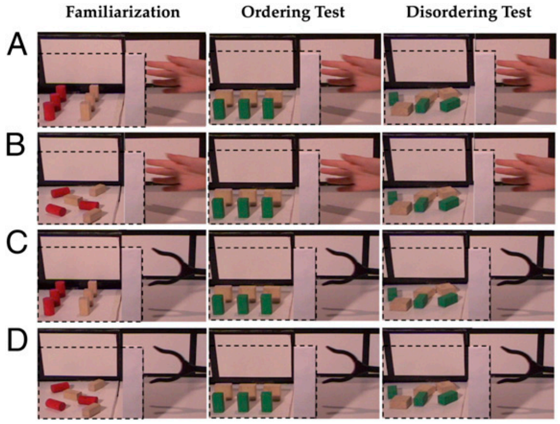

Fig. 4. Depiction of the events presented to infants in experiment 3. Each picture shows the outcome of that particular movie and the type of entity involved. The dotted box outlines the opaque screen that was raised and lowered to reveal the outcome. (*Left column*) The type of familiarization, including: (*A*) hand-ordering familiarization, (*B*) hand-disordering familiarization, (*C*) claw-ordering familiarization, and (*D*) claw-disordering familiarization. *Middle column* and *Right column* depict the ordering and disordering test events, respectively, that followed familiarization.

infants in the claw conditions would look longer at the ordering test events than at the disordering test events.

To examine infants' expectations about agents, we presented infants with similar video sequences as in the claw conditions, except that the inanimate claw was replaced with a human hand. During the familiarization events, half of the infants saw movies in which the hand appeared to create order (hand-ordering familiarization), and the other half saw movies in which the hand appeared to create disorder (hand-disordering familiarization). Following familiarization, infants in both conditions saw alternating test events in which the hand appeared to create order (ordering test event) and to create disorder (disordering test event) using a new set of blocks.

Our logic here was that, if infants expect agents to be capable of creating either order or disorder, then the type of event shown during familiarization should bias infants' pattern of looking during test events. Specifically, infants exposed to the hand-ordering familiarization events should subsequently expect the person to continue to create order. Thus, in test events, the infants should look longer when the hand creates disorder than when it continues to create order. Conversely, infants exposed to the hand-disordering familiarization event should expect the person to continue to create disorder. Therefore, in test events they should look longer when the hand appears to create order than when it continues to create disorder.[§]

Results and Discussion. Given that this study presented infants with multiple repetitions of very similar displays, several infants became inattentive in later trials. Therefore, our primary analysis reports looking times in the only first pair of test trials. The effects, however, were the same when the analyses were performed on all three test pairs.

As seen in Fig. 5, the looking time data indicated that, regardless of the type of familiarization event, infants in the claw conditions looked reliably longer at the inanimate claw creating order (M = 17.77 s, SE = 1.67) than at the claw creating disorder [(M = 13.31 s, SE = 1.97), $F(1, 24) = 7.02$, $P = 0.014$, η_p^2 = 0.23]. As predicted, this pattern was observed following both the disordering familiarization event (Ms = 19.6 s and 14.4 s, respectively) and the ordering familiarization event (Ms = 16.0 s and 12.2 s, respectively).

In contrast, infants observing in the hand conditions looked reliably longer at the hand creating disorder (M = 14.13 s, SE = 1.53) than at the hand creating order [(M = 9.39 s, SE = 1.29), $F(1, 24)$ = 7.66, $P = 0.011$, η_p^2 =0.24]. This pattern was observed following both the disordering familiarization event (Ms = 13.3 and 10.2, respectively) and the ordering familiarization event (Ms = 14.9 and 8.6, respectively).

We conducted a 2 × 2 × 2 omnibus ANOVA with familiarization event (ordering vs. disordering) and entity type (hand vs. claw) as between-subjects factors and test event type (ordering vs. disordering) as a within-subjects factor. This analysis revealed a significant two-way interaction between entity type and test event type [$F(1,48) = 14.67$, $P < 0.001$, $\eta_p^2 = 0.23$]. This two-way interaction was also significant when an identical analysis was performed on the average looking time across all three pairs of test trials [$F(1,48) = 20.34$, $P < 0.001$, $\eta_p^2 = 0.30$]. However, there was no three-way interaction with the type of familiarization event ($F < 1$), and no other main effects or interactions were observed. In other words, the interaction effect for infants to look longer at the inanimate claw creating order, but longer at the animate hand creating disorder, was obtained following both the ordering familiarization events [$F(1, 26) = 10.45$, $P = 0.003$, η_p^2 =0.29] and the disordering familiarization events [$F(1,22) = 5.04$, $P = 0.035$, $\eta_p^2 = 0.19$].

Nonparametric analyses of the data revealed a similar pattern. Following the disordering familiarization, 9 of 12 infants in the hand condition looked longer at the first disordering test event, whereas 10 of 12 infants in the claw condition looked longer at the first ordering test event ($P = 0.012$ via a two-tailed Fisher's exact test). Similarly, following the ordering familiarization, 10 of 14 infants in the hand condition looked longer at the first disordering test event, whereas 11 of 14 infants in the claw condition looked longer at the first ordering test event ($P = 0.021$ via a two-tailed Fisher's exact test). These results were the same when examining the looking time patterns across all three test pairs.

Analysis of the familiarization events indicated that infants' looking decreased across trials ($P = 0.02$). Moreover, in the first familiarization event, infants tended to look longer at the claw-ordering event (M = 20.3 s, SE=2.31) than at the other three familiarization events (Ms = 17.2 s, 18.0 s, and 18.1 s), although this difference did not reach statistical significance.

Thus, results from experiment 3 suggested that by 12 mo of age infants have a robust expectation that inanimate objects cannot create order. Even when given experience during familiarization that an inanimate claw can create order, infants still looked longer at the test event in which the claw continued to create order compared with when the claw created disorder. This provides strong confirmation that infants do not consider it likely that inanimate objects can create order.

With respect to infants' expectations about agents, the results from this study suggested that infants at this age do not find an agent creating order and an agent creating disorder to be equally likely. Both the ordering and disordering familiarization events led infants to consider hands creating order to be more likely than hands creating disorder. It appears that the familiarization events made the causal interaction between the hand and the blocks more salient and thus led infants to expect the creation of order, rather than the creation of disorder. This pattern, however, is different from the null result obtained in experiment 2. One explanation for this difference may be that infants have formed a strong expectation that people tend to create order, which was sufficient to override any effects of the familiarization events. The difference in looking-time patterns across experiments between experiments 2 and 3 therefore may have occurred because infants have

[§]This study used an experimental logic developed by other infant researchers to demonstrate that infants expect agents (human hands), but not inanimate objects (sticks), to have consistent object-specific goals (12, 13, 25).

PSYCHOLOGICAL AND COGNITIVE SCIENCES

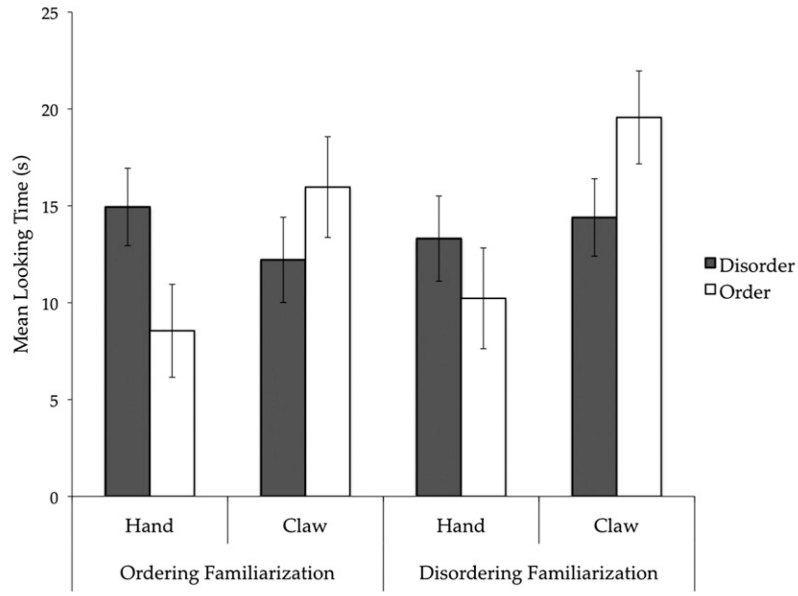

Fig. 5. Mean time (in seconds) spent looking at the first ordering and disordering test events in all conditions of experiment 3 (±SE).

formed reliable expectations about people (experiment 3), but they have less robust expectations about a novel animated character (experiment 2).

General Discussion

The present studies suggest that, by at least 12 mo of age, infants appreciate that agents are capable of creating order, whereas inanimate objects are not. Moreover, at 4 y of age, children readily identify that, whereas agents are capable of creating either order or disorder, inanimate forces (such as the wind) are capable of creating only disorder. This understanding represents competence in an entirely new category of physical principles that integrates knowledge from both the physical and social domains. Accurate expectations about how agents and inanimate objects differ in their ability to create order requires that, in some sense, young children blend together intuitive concepts of simple inanimate objects (their folk physics) with their intuitive concepts of other social agents (their folk psychology). The computational and representational requirements of such mental abilities would seem to be quite complex; however, the presence of such abilities in infants raises important questions about how such an understanding might be achieved.

Moreover, these findings potentially offer insight into a larger class of causal inferences that occur somewhat later in development. Although previous work has established that adults, infants, and even nonhuman primates are often remarkably accurate at identifying appropriate causal agents, there also appear to be systematic ways in which children and adults are prone to agentic or teleological explanations. For example, 4-y-old children will report that lakes are "for swimming," or when asked about the origins of animals and people, tend to endorse explanations that include an intentional creator (26–28). In addition, cross-cultural work finds striking commonalities in the prevalence of "intelligent design" arguments among children and adults (29–32).

One explanation for these types of inferences is that, in our everyday experiences, ordered phenomena do tend to result only from other agents. The correlation is simply too strong and salient to ignore. Moreover, it is well known that adults and children often have a difficult time reasoning about randomness and its effects (33–35). Thus, in certain situations, we may overextend a causal framework that includes strong connections between agents and order to erroneously see some ordered patterns as intentionally created by an agent, even when the ordered pattern is actually created by an unintentional, inanimate process. Although future work is necessary to determine exactly how (or, if) expectations about ordering blocks and inferences about biological creation are related, the present findings at least open the door for the idea that biases to see agents as responsible for order (in many different domains) may be rooted in fundamental causal appreciations that emerge within the first year of life.

Materials and Methods

Age and sex specifics are as follows: experiment 1 included 40 children (25 male, 15 female), divided into two age ranges: 20 children aged 3–4 (M_{age} = 4 y 2 mo; range: 3 y 4 mo to 4 y 8 mo) and 20 children aged 5–6 (M_{age} = 5 y 7 mo; range: 5 y 2 mo to 6 y 8 mo). The children were all enrolled as students in daycare, prekindergarten, or kindergarten programs in public or private schools. Experiment 2 included 48 infants divided into two age groups: 24 infants aged 12 mo (12 male, 12 female) with a mean age of 12 mo 24 d (range: 11 mo 15 d to 13 mo 26 d) and 24 infants aged 7 mo (18 male, 6 female) with a mean age of 7 mo 2 d (range: 6 mo 17 d to 7 mo 18 d). Experiment 3 included 52 infants (24 male, 28 female) with a mean age of 12 mo 14 d (range: 11 mo 6 d to 13 mo 26 d). An additional 42 infants were tested but were excluded because of inattention (experiment 2: n = 12 infants aged 12 mo; n = 11 infants aged 7 mo; experiment 3: n = 14), or experimenter error (experiment 2: n = 3; experiment 3: n = 2). In experiment 2 (hand condition), the data from one outlier (>2.5 SDs from mean difference score) was discarded and replaced with an additional participant's data.

In experiments 2 and 3, we used a violation of expectation looking-time procedure. For each experiment, we predicted longer looking times to unexpected events than to expected events. To be included in analyses, subjects had to see at least two complete pairs of test trials, out of a possible three pairs. A given test trial was considered to be complete if the infant watched for at least the length of time it took for the inanimate object or agent to travel behind the opaque barrier. The number of infants who saw only two complete pairs were as follows: experiment 2 (n = 7 infants aged 12 mo; n = 6 infants aged 7 mo); experiment 3 (n = 25 infants aged 12 mo). An observer, who was hidden behind a curtain and was unaware of the infant's experimental group, measured looking time on each trial using computerized timing software. In test trials, timing began when the opaque barrier was lowered to reveal the final outcome display. In experiment 2, the test movie remained "frozen" on the final outcome display until the trial ended. In experiment 3, the movie was looped continuously until the trial ended. A given trial ended if an infant looked away for more than 2 continuous seconds, or if 30 s elapsed. A second experimenter, also naive to the infants' experimental group, reviewed video footage from a subset (25%) of the infants and recorded their looking times to the test movies. Interobserver reliability across experiments was high (r = 0.97 or greater); thus all data analyses were performed using results from the on-line timing.

ACKNOWLEDGMENTS. We thank Ashley Norman, Russell Ritchie, Sarah Thompson, and members of the Yale Infant Cognition Laboratory for their help in conducting the experiments. This work was supported by National Institutes of Health (NIH) Grant R37HD023922 (to F.C.K.), National Science Foundation Grant 1018733 (to K.W.), NIH Grant F2MH64269 (to V.A.K.), and a grant from the Natural Sciences and Engineering Research Council (Canada) (to V.A.K).

1. Fisher CB, Ferdinandsen K, Bornstein MH (1981) The role of symmetry in infant form discrimination. *Child Dev* 52:457–462.
2. Saffran JR, Aslin RN, Newport EL (1996) Statistical learning by 8-month-old infants. *Science* 274:1926–1928.
3. Wentworth N, Haith MM, Hood R (2002) Spatiotemporal regularity and interevent contingencies as information for infants' visual expectations. *Infancy* 3:303–321.
4. Fiser J, Aslin RN (2002) Statistical learning of new visual feature combinations by infants. *Proc Natl Acad Sci USA* 99:15822–15826.
5. Xu F, Garcia V (2008) Intuitive statistics by 8-month-old infants. *Proc Natl Acad Sci USA* 105:5012–5015.
6. Kuhlmeier VA, Bloom P, Wynn K (2004) Do 5-month-old infants see humans as material objects? *Cognition* 94:95–103.
7. Meltzoff A (1995) Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Dev Psychol* 31:838–850.
8. Poulin-Dubois D, Lepage A, Ferland D (1996) Infants' concept of animacy. *Cogn Dev* 11:19–36.
9. Gergely G, Nádasdy Z, Csibra G, Bíró S (1995) Taking the intentional stance at 12 months of age. *Cognition* 56:165–193.
10. Saxe R, Tenenbaum JB, Carey S (2005) Secret agents: Inferences about hidden causes by 10- and 12-month-old infants. *Psychol Sci* 16:995–1001.
11. Spelke ES, Phillips A, Woodward AL (1995) *Causal Cognition: A Multidisciplinary Debate*, eds Sperber D, Premack D, Premack AJ (Oxford University Press, Oxford), pp 44–78.
12. Woodward AL (1998) Infants selectively encode the goal object of an actor's reach. *Cognition* 69:1–34.
13. Leslie A (1984) Infant perception of a manual pick-up event. *Br J Dev Psychol* 2:19–32.
14. Friedman WJ (2001) The development of an intuitive understanding of entropy. *Child Dev* 72:460–473.
15. Friedman WJ (2002) Arrows of time in infancy: The representation of temporal-causal invariances. *Cogn Psychol* 44:252–296.
16. Friedman WJ (2003) Arrows of time in early childhood. *Child Dev* 74:155–167.
17. Johnson S, Slaughter V, Carey S (1998) Whose gaze will infants follow? The elicitation of gaze-following in 12-month-olds. *Dev Sci* 1:233–238.
18. Gelman R (1990) First principles organize attention to and learning about relevant data: Number and the animate-inanimate distinction as examples. *Cogn Sci* 14: 79–106.
19. Spelke ES (1985) *Measurement of Audition and Vision in the First Year of Postnatal Life: A Methodological Overview*, eds Gottlieb G, Krasnegor N (Ablex Publishing, Westport, CT), pp 85–168.
20. Spelke ES, Breinlinger K, Macomber J, Jacobson K (1992) Origins of knowledge. *Psychol Rev* 99:605–632.
21. Wynn K (1992) Addition and subtraction by human infants. *Nature* 358:749–750.
22. Onishi KH, Baillargeon R (2005) Do 15-month-old infants understand false beliefs? *Science* 308:255–258.
23. Keil FC (1989) *Concepts, Kinds, and Cognitive development* (MIT Press, Cambridge, MA).
24. Carey S (2009) *The Origin of Concepts* (Oxford University Press, New York).
25. Song HJ, Baillargeon R (2007) Can 9.5-month-old infants attribute to an agent a disposition to perform a particular action on objects? *Acta Psychol (Amst)* 124: 79–105.
26. DiYanni C, Kelemen D (2005) Time to get a new mountain? The role of function in children's conceptions of natural kinds. *Cognition* 97:327–335.
27. Kelemen D (2004) Are children "intuitive theists"? Reasoning about purpose and design in nature. *Psychol Sci* 15:285–301.
28. Kelemen D (1999) Why are rocks pointy? Children's preference for teleological explanations of the natural world. *Dev Psychol* 35:1440–1452.
29. Evans EM (2001) Cognitive and contextual factors in the emergence of diverse belief systems: Creation versus evolution. *Cogn Psychol* 42:217–266.
30. Evans EM (2000) The emergence of beliefs about the origins of species in school-age children. *Merrill-Palmer Q* 46:221–254.
31. Kelemen D (2003) British and American children's preferences for teleo-functional explanations of the natural world. *Cognition* 88:201–221.
32. Kelemen D, DiYanni C (2005) Intuitions about origins: Purpose and intelligent design in children's reasoning about nature. *J Cogn Dev* 6:3–31.
33. Kahneman D, Tversky A (1972) Subjective probability: A judgment of representativeness. *Cogn Psychol* 3:430–454.
34. Metz K (1998) Emergent understanding and attribution of randomness: Comparative analysis of the reasoning of primary grade children and undergraduates. *Cogn Instr* 16:285–365.
35. Piaget J, Inhelder B (1975) *The Origin of the Idea of Chance in Children* (Routledge & Kegan Paul, London).