Order, Order Everywhere, and Only an Agent to Think: The Cognitive Compulsion to Infer Intentional Agents

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Abstract: Several studies demonstrate that an intuitive link between agents and order emerges within the first year of life. This appreciation seems importantly related to similar forms of inference, such as the Argument from Design. We suggest, however, that infants and young children may be more accurate in their tendencies to infer agents from order than older children and adults, who often infer intentional agents when there are none. Thus, the earliest inferences about intentional agents based on order may be quite accurate and resistant to non-intentional foils, but with further cognitive development and overgeneralization, links between order and agents may emerge that, with the right socio-cultural prompts, can lead to the Argument from Design.

The world around us consists of two fundamentally different forms of patterns: those that appear random and those that appear ordered. Order may be perceived in any number of modalities and in many different forms, whether it be via axes of symmetry, spatial or temporal sorting, or complex structural arrangements. Moreover, as adults, we often associate the presence of order with other goal-directed actors (or, agents). For example, Bowerbirds meticulously arrange objects to form an elaborate nest designed to attract a mate. Spiders spin ornate webs designed to catch prey. Or, a parent may spend hours carefully stacking and sorting items in a child's room (only to have their efforts quickly undone). In all these cases, we clearly see the mark of intentional action—we recognize that these goal-directed actors have the capacity to manipulate, organize, and structure the world around them such that they create arrangements that deviate from random or chance occurrences.

We do not, however, see simple inanimate objects as capable of having such effects. Throw a stone, roll a ball, or slide a block at a disordered group of objects and it is highly unlikely that any of those events will make a more ordered arrangement. We would be surprised to see such an effect because we normally assume that order arises from the intentional actions of agents, not the simple mechanical causes of inanimate objects. Thus, one major division in the world of causal entities is between those that are capable of creating order and those that are not.

Beyond an understanding of simple arrays such as the arrangement of objects, the link between agents and order may also serve as a powerful analogy for beliefs about

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Preparation of this paper and some of the research described in was supported by NIH grant R37-HD023922 to F. Keil.
The article title comes with apologies to Coleridge ('The Rime of the Ancient Mariner', 1798).

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Mind & Language, Vol. 30, No. 2 April 2015, pp. 117–139.

creation in the natural world. For example, the tendency to use intentional agents to explain the existence of order has often been cited as the reason why people throughout history have used versions of the 'Argument from Design' to motivate intentional deities who create an ordered universe (Dawkins, 1996).

In this article we will focus on the relationship between agents and order and in particular, how inferences linking agents and order emerge and change throughout the course of development. Specifically, we will review research demonstrating that an understanding of a relationship between agents and order emerges within the first year of life, and we will present new data, which attempts to reduce that appreciation to a set of more primitive assumptions about deviations from statistical regularity. We will also suggest that infants and young children may in fact, be more accurate and less 'hyperactive' in their tendencies to infer agents from order than older children and adults. Finally, we will suggest that related patterns of inference, such as the Argument from Design, take time to develop due to the apparent overgeneralization of rules such as, 'order *must* arise from agents'. That is, the most developmentally early ways in which order drives inferences about intentional agents may be quite accurate and hard to fool through non-intentional means, but with the development of more abstract thought, perceived regularities may be overgeneralized to instances in which the link between order and agents is suggested, but in fact, unfounded.

1. Inferring Order from Static Cases

It might seem that the simplest way that order triggers beliefs in intentional agents is when we look at a static array, see order, and think an agent must have been responsible. This can occur with varying degrees of vividness, as can be seen in the work of artists who may gently increase the relative order of a natural scene. An especially compelling set of cases is found in the works of the artist, Andy Goldsworthy. Goldsworthy frequently creates settings in nature where there is an irresistible suggestion of some form of order. For example, one striking case involves a meadow full of bright yellow dandelions, but with a particularly dense line of those flowers snaking across the terrain away from the viewer almost to the horizon (see http://prettisculpture.typepad.com/photos/other_artists_3/goldsworthyyellowline dandelion.html). The line is not perfectly straight and is composed of only flowers but against the backdrop of more randomly scattered flowers of the same type, it jumps out as strikingly different. Another case involves a collection of six flat, oval stones lying in the dirt. Each stone has been broken into exactly three pieces and then put back together in its original shape to create a smooth exterior contour around each of the stones (see https://grayravendesigns.files.wordpress.com/2012/03/andy-goldsworthy-cracked-broken-pebbles-1978.jpg; or http://andfunforall.blogspot.com/2008/01/land-art-andy-goldsworthy.html). The individual pieces are somewhat jagged and have unique shapes, but the viewer is drawn to the consistent repetition of each stone being fractured into three parts. It is conceivable that one stone could have been dropped or struck in such manner that it yielded three parts, but it is very different to see six stones all broken into exactly three.

Why is there a strong sense that such arrays must have been created by an agent? Although the inference itself may seem somewhat effortless, in reality, the cognitions necessary to infer agents from a static ordered array (such as those just described) are quite complex. For example, it is not based on merely perceptual cues that reliably distinguish artifacts from natural kinds, such as straight edges or right angles (e.g. Levin, Takarae, Miner and Keil, 2001). Indeed, the arrays of flowers and stones are composed of all natural materials with no perfectly straight edges or right angles. Moreover, the arrays that we may recognize as 'ordered' are extraordinarily diverse, including various perceptual groupings, arrangements along axes of symmetries, complimentary spatial arrays that preserve relations between objects (e.g. the smaller item is always on top of the larger one), etc. And yet, such inferences do not appear to be invariably triggered by just any case of non-randomness. For example, most people do not infer intentional agents as behind the formation of rainbows, snowflakes or soap bubbles. Similarly, the flat surface of the water on a pond is non-random but not agent-inducing.

We suggest that at least three factors may be at work when static ordered arrays elicit inferences of an intentional agent: (a) a strong before state is implied, (b) the array/regularity itself is fairly uncommon, and (c) a design or function is implied.

First, agent inferences may be more common when there is a strong prior or alternative (less ordered) state of the world that is implied. For example, a field full of flowers with one line of flowers running through the middle seems to suggest that at one point, the arrangement of all of the flowers was random. A set of rocks that are all broken into three pieces strongly suggests that at an earlier time, the rocks were intact. That is, order in a static scene elicits thoughts of intentional agents when one envisions prior states and imagines causal paths from the prior state to the present. In contrast, there is no salient before state for a rainbow or a snowflake. They just seem to appear and no obvious transformation is suggested.

Second, when a case of non-randomness is commonplace, as it is for snowflakes or rainbows, it may be harder to imagine an intentional agent dutifully going to the trouble of creating each and every snowflake or each and every rainbow. This difficulty imagining such an agent may also arise from strong constraints on what counts as a plausible agent. For example, even adults who consciously profess having a completely omnipotent view of God, nonetheless tend to understand narratives involving God in ways that have distinctly human cognitive constraints (Barrett and Keil, 1996). Thus, constraints on how we think about intentional agents will make some arrays more 'agent-compelling' than others.

Third, in some instances (but not so much in the Goldsworthy cases described earlier), there is a strong sense of the non-random elements having a function or purpose. The conditions that give rise to a sense of function and purpose are complex and not fully understood—they can range from simple Gibsonian affordances (Gibson, 1977) to cases of intricate design. But even here, there are hidden complexities. After all, a completely naturally occurring rock might, because of its shape and composition, ideally serve the function of being a paperweight, hammer, or weapon. So, for an object with a function to trigger a sense of an intentional agent there still seems to be a necessary judgment that the function could not have occurred by chance, by accident or by 'natural causes'.

One facet cutting across all of these factors (consideration of prior states, the frequency of the array itself, functionality) seems to be the idea that it is highly improbable that the array could have been created by 'natural means', meaning without the assistance of intentional agents—an idea that has been discussed extensively elsewhere (e.g. Dawkins, 1996). Such inferences involve imagining how a snaking line of flowers or a grouping of rock fragments could have happened through mere acts of nature such as a strong wind, a landslide, a flood or some other non-human event. Therefore, inferring agents from order would seem require several conceptual tasks: detecting certain kinds of non-randomness, reconstructing prior events with specified time frames that led to that non-randomness, and assessing the causal plausibility that the array arose from unintentional natural causes verses the plausibility that it was caused by an agent. This latter appreciation further requires knowledge about what is a very large set of plausible causal pathways in nature and what is outside that sphere, as well as what is a plausible outcome of human activity.

Given the sheer complexity of integrating these different appreciations, it may take many years to intuitively link agents to static, ordered arrays. Infants and young children would seem to be unlikely to engage in such reflective evaluations and one does not typically observe infants regarding natural order with wonder or young children asking how the complex structures and functions of flowers could have come about. So, it might seem that any drive to infer agents from order is a relatively late developing cognitive ability that requires considerable learning about the real world as well as substantial working memory and skills in reasoning about intentions.

2. Inferring Order from Changes in Order

We have argued that inferring agents from static ordered arrangements may be a complex process not available to the minds of younger humans. Almost paradoxically, however, we suggest that seeing a more complex situation, namely an event in which a system changes from relative disorder to order, may be accessible at a much earlier age. Perhaps in such cases, one needs to know less about real world causal patterns and just needs to evaluate a local pattern of change.

Consider the situation where one encounters a scattered pile of blocks of different shapes in a seemingly random array. Some time later, imagine that one observes the same items neatly ordered by shape (see Figure 1), but did not see what happened in between. In such cases, there seems to be a powerful sense that the event could only have occurred because of an intentional agent. In contrast, when one sees an ordered array of blocks that then becomes disordered, a much wider range of causes seems plausible: intentional agents, but also non-intentional, inanimate causes, such as a huge surge of wind, an errant ball, or even an earthquake.

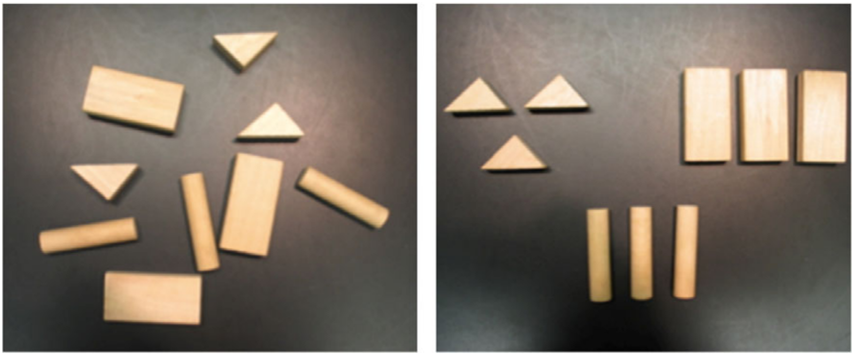

Figure 1 *Change from Relative Disorder to Relative Order.*

Such events may require less background knowledge to infer agents than static arrays. In this case one may only need to recognize differences in the relative order of the two displays and appreciate that changes in one causal direction (disorder to order) tend only to arise from agents. Thus, the same child who is not compelled to infer intentional agents when looking at the symmetrical pedals of a flower might do so for these simple events that require less real world knowledge. Indeed, we suggest that the foundation for inferring agency from order in general might even spring from observations of these simple events, such as when a parent cleans up a child's room.

2.1 A Study with Young Children

Do young children appreciate that only agents can create order from disorder? We asked this question by introducing 3–6-year-olds to a picture of a room with blocks lying on the floor. The room was described as being in that condition when a boy, Billy, left it. Then the children were told that while Billy was outside, either the wind blew strongly though the window and changed things (inanimate condition) or his older sister went into the room and changed things (animate condition). The children were then presented with a pair of pictures (ordered in a new way and disordered in new way) and asked which one looked most like the wind had changed it, or which one looked most like the girl had changed it, depending on condition (Newman *et al.*, 2010). The children almost invariably said that the wind must have caused the disordered outcome, but that the person could cause either the ordered or disordered outcome.

More impressively, in another study (Keil and Newman, 2008), children of the same age tended to associate only agents with even more subtle forms of ordering. For example, they associated intentional agents with higher forms of order, such as the arrays depicted in Figure 2. In this case, the 'order' relies on preserving a consistent complementary relationship among the elements (e.g. erasers inside of the rings), but the arrangement itself is not organized along traditional Gestalt

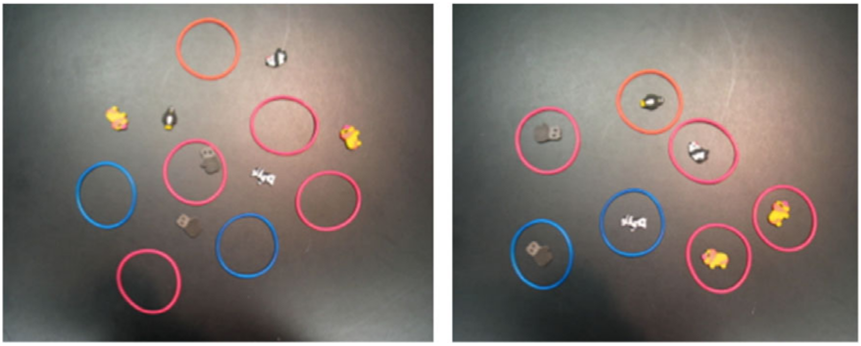

Figure 2 *A More Complex Change in Order in Which an Abstract Relationship is Preserved (taken from Keil and Newman, 2008).*

dimensions, such as an axis of symmetry. Therefore, whatever the 3-year-olds are picking up on cannot be reduced to simple perceptual parameters such as straight lines, or any other relatively low-level perceptual clues.

We asked the children in all these ordering studies why they were so convinced that only the agent could cause the ordered outcomes. Many children simply shrugged or re-described the array in terms of order or aesthetics (e.g. '*She made it like that because it was beautiful*'.). Their judgments seem analogous to moral dumbfounding in which participants can have strong intuitions but be unable to justify them (Haidt, 2001). Indeed, even adults may even have similar challenges in providing detailed descriptions of the origins or order. The inability to access reasons for the young children's responses suggested to us that perhaps the intuitions about agents and ordering have much earlier roots. Accordingly, we conducted a series of studies with preverbal infants.

2.2 Infant Intuitions about Order and Agents

In our first infant study, we presented 12- and 7-month-old infants (Newman *et al.*, 2010) with the display shown in Figure 3. Infants in the Ordering events first saw a disordered array of blocks. Then a screen covered the blocks and either an intentional agent (a character with a human face that moved in a goal-directed manner) or a ball (that spun inanimately) moved behind the screen. The screen then dropped to reveal the blocks in an ordered array. In the Disordering events the displays were identical. However, the sequence of events was reversed such that it now appeared that the object (agent or ball) changed the ordered pile to a disordered array. To measure whether infants recognized a difference between these types of events, we used a violation of expectation paradigm, which is based on the well-documented finding that infants tend to look longer at displays that violate their expectations (e.g. Baillargeon, 2004).

The 12-month-old infants looked equally long when the agent created order or disorder, suggesting that they found neither event particularly novel. However,

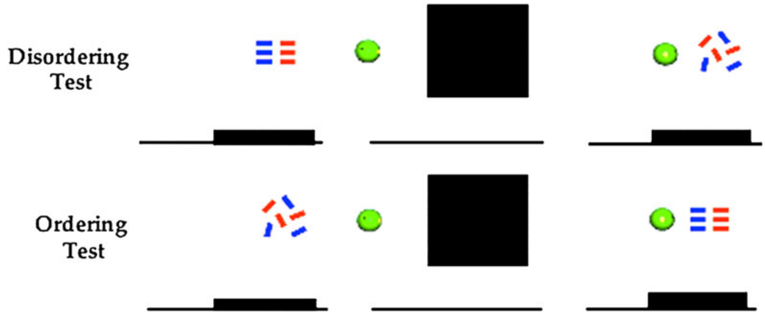

Figure 3 *Ordering and Disordering Test Events (taken from Newman et al., 2010).*

in the case of the inanimate ball, the infants looked reliably longer when the ball appeared to create order than when it appeared to create disorder. By contrast, the 7-month-old infants simply tended to look longer at the sequences involving the agent (perhaps because they found it more interesting) and showed no looking differences as function of whether animate versus inanimate agents were associated with ordering events. Together, these results suggested by at least 12 months of age, infants seem to have some appreciation that changes from relative disorder to order are likely to result only from goal-directed agents.

In our second infant study (Newman *et al.*, 2010), we used a very different paradigm to test the generality of the results with preverbal infants. In this task, we familiarized 12-month-old infants to a video of either a hand or a claw that engaged in either 'ordering' 3-dimensional blocks or 'disordering' the same blocks. Several prior studies have shown that infants, well before 12 months, expect hands to act in goal-directed ways and claws to act in non-goal-directed more mechanical ways (Leslie, 1984; Woodward, 1998).

When infants were familiarized to a hand creating order, they looked longer when it subsequently created disorder (as in, the person had changed their goals). However, even if they were familiarized to the claw creating order, they still looked longer if the claw continued to create order with new blocks than if it changed to creating disorder. Thus, even if the claw changed its action type to disordering, infants looked longer when it continued to engage in the same kind of unexpected action. The opposite pattern arose when familiarized to a disorderer. If it was a hand, the infants had a slight expectation that it should be an orderer no matter what, looking longer if it continued to disorder, and a strong expectation that the claw should be a disorderer no matter what, thus looking much longer when the claw went from disordering to ordering.

Taken together, the results across these two studies demonstrate a seemingly robust expectation in preverbal infants that intentional agents, or strong indicators of intentional agents (e.g. hands) are the only entities capable of changing a set of objects from a state of relative disorder to one of relative order. They apparently have these intuitions without any need for verbal representations to mediate their reasoning.

This suggests that the intuitions in older children and adults may indeed be automatic and much like those that drive phenomena such as moral dumfounding (Haidt, 2001).

More recently, a different research group has shown a conceptually similar phenomenon with 9-month-old infants in a very different kind of task (Ma and Xu, 2013). Infants watched balls come out from behind a screen into a clear tube over successive events where in each event the balls either always came out into the clear tube in exactly same regular patterned order (e.g. 2 reds, 1 yellow, 2 reds, 1 yellow ...) or in completely random orders of yellow and red balls. After several such trials or either successive ordered sequences or successive random ones, the screens were raised to reveal a large beaker full of a mixture of many red and yellow balls with either a claw removing balls and putting them into a chute leading to the clear tube or a hand doing so. The infants looked longer when the claw was associated with the regular non-random displays and showed no difference in looking with the random displays. Thus, a very different way of creating order, namely forming regular sequences from a random source, was associated with markers of intentional agency.

In short, across three markedly different stimulus conditions and methodologies, preverbal infants as young as 9 months consistently have strong intuitions that only agents are capable of creating order. These intuitions then stay in force in early childhood but seem automatic and unavailable to explicit justifications—even adults may have difficulty explaining them.

3. Reducing the Phenomenon to Regularities: The Palm and the Pendulum

We have seen that a particular sequence of events can elicit in preverbal infants strong intuitions about whether the cause was an intentional agent. But how do infants decide on what an intentional agent is? Is it based on low-level perceptual cues like eyes, or hands or a particular way of moving in real time, or is it instead a result of the setting up of a more abstract interpretative framework in which completely novel non-normative agents can also be seen take on intentional roles when the embedding context suggests as much? That is, are even infants able to grant intentional agency to completely non-human, non-animal entities when we set up a different way of construing them?

Answers to this question start to get at the issue of just how conceptually based, as opposed to perceptually based, the links between agents and ordering are. Given the range of ordering types in the three infant studies just described, we have strong indications that there are no simple perceptual configurations that trigger a sense of ordering; but it would be useful to know if inferences about intentional agents as well can be detached from local immediate perceptual cues. We do know that there are many highly contextually specific perceptual cues to some forms of agency such as simple animacy (e.g. certain trajectories, such as chasing, see Gao *et al.*, 2009; or

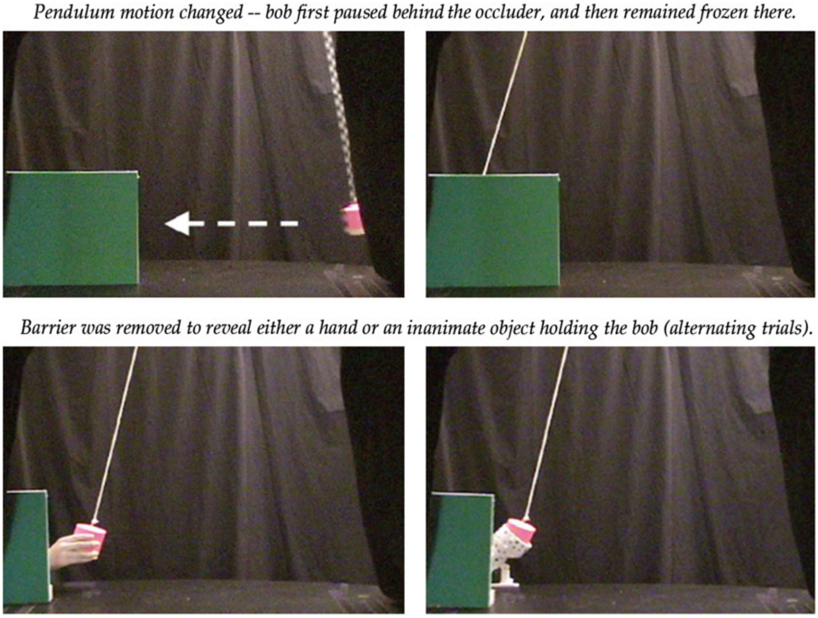

Figure 4 *Test Events for Experimental Conditions in the 'Pendulum', Study 1.*

launching for inanimate causality, see Newman *et al.*, 2008); but can there be cases in which a more abstract framework is set up where a normally inanimate entity is considered an intentional agent?

To explore this idea, we conducted a study with 13-month-olds,[1] asking if they recognize that only intentional agents can intervene on a system so as to take advantage of structural regularities that depend on timing and location. Infants saw two different short movies, presented in alternating order (see Figure 4). In the Animate (hand) test events, a pendulum entered the display from off screen on the right-hand side. The pendulum continued to swing across the stage until it passed behind an opaque barrier. At this point, however, the motion of the pendulum abruptly stopped (as evidenced by the cessation of motion in the rope). The pendulum remained briefly frozen behind the barrier for approximately 1 second before it was released and swung back toward the right-hand side of the screen. When the pendulum reversed directions and again swung behind the barrier it again stopped and remained frozen there. At this point, the barrier was removed to reveal an experimenter's hand holding the pendulum. The movie then paused with the hand holding the pendulum, and infants' looking-time was recorded.

In Inanimate (lamp) test events, infants were exposed to nearly the identical sequence of events. In fact, the motion of the pendulum was identical to the Animate

[1] Please see the Appendices for a full reporting of all methods and results.

condition, which was accomplished by splicing the video at a point in which the pendulum was frozen behind the barrier for the second time. Unlike the Animate condition, however, when the barrier was removed, it revealed the cylinder resting inside the lip of the lamp.

When we showed infants these events, we observed a phenomenon similar to the ordering studies. Infants looked reliably longer at the Inanimate test events than at the Animate test events. This result is consistent with the idea that only the hand was seen as capable of intervening on the pendulum, in essence, anticipating certain critical event transitions as moments for action—abruptly halting it and then seemingly, releasing it. Equally important, however, is that this paradigm allowed us to then explore just how conceptually abstract an intentional agent can be.

In a second study, prior to watching the pendulum movies, infants were shown a segment from the short animated film, *Luxo Jr* by Pixar animations, which features a white desk lamp that exhibits several animate cues—e.g. biological motion, contingent action, and goal-directed behavior. After this movie was played once, infants were then presented with the same familiarization and test events involving the pendulum. A second set of control conditions was also included where infants watched a movie that consisted of still frames taken from the *Luxo Jr* movie. The still frames were presented in a sequence that corresponded to the sequence in the actual *Luxo Jr* movie. To equate for the presence of motion, the still frames in the control movie slowly panned to the left or to the right of the screen, such that the display contained motion, but not biological motion. Hence, all of the stimulus dimensions were equated nearly identically across the Luxo and Control movies, with the one critical exception that the Luxo movie clearly portrayed a lamp behaving animately, while the control movie clearly did not.

When we then showed infants the pendulum movies, we observed that infants who had previously watched the animated Luxo movie looked equally long at the Inanimate (lamp) outcome as they did to the Animate (hand) outcome, which is consistent with the notion that the animate motion of the Luxo familiarization encouraged infants to think of the lamp as more animate. In contrast, infants who had watched the Control movie looked reliably longer at the lamp movies than at the hand movie (which was the same pattern as observed in the first study).

Across the two studies, the general finding supports a highly abstract representation that only intentional agents can intervene on the world and create certain changes, but that almost any entities can be possible intentional agents with appropriate framing contexts. Thus, there seem to be certain modes of construal that get activated by specific event properties but then can be used to interpret future events. This early flexibility suggests how unusual agency attributions might get set up and are maintained. If prior events, or even cultural practices and rituals, suggest that a certain entity can be an intentional agent, one might then accept its role in future event interpretations and even find confirming evidence even though that 'evidence' arises from a single early 'slot' assignment. We will return to this idea in more detail later.

4. Agents and Intelligence

In the studies described so far, infants and young children have strong expectations about links between ordering events and intentional agents. But, what level of intelligence do they attribute to those intentional agents? And, how might those attributions shift with increasing knowledge?

First consider, for example, how adult intuitions may operate for the ordering stimuli shown in Figures 1 and 2. Most adults would assume that preverbal infants and non-human creatures are not capable of creating such ordered arrays. They seem to assume that a combination of cognitive skills involving explicit planning, idealized models and abstract rules are needed and are beyond the skill levels of babies and most non-humans. Cases such as bird nests and spider webs are not considered counter examples because they are seen as being more automatic and not the results of highly flexible model building, such as grouping by category or more complex spatial arrangements (cf. Figure 2)

Given the apparent complexities required to make these inferences, how might young children and even infants represent such events? Perhaps infants and young children assume that any goal directed agent is capable of creating order. Or, perhaps they have more fine-grained expectations and envision some level of intelligence as being required. We have not done extensive explorations here, but a story is suggested by a preliminary study conducted with preschoolers (see Keil and Newman, 2008, for further details).

Young children (Kindergarteners, aged 3 to 4, and second graders, aged 5 to 6) were presented with changes from disorder to order, like those depicted in Figures 1 and 2. The types of order spanned a wide range of types and complexity. In all cases, children were first shown a photograph of a disordered arrangement. They were then shown a photograph of the same objects in an ordered array. The experimenter would ask children to first describe what had changed: '*What do you notice about these pictures? What has changed?*'

After the child acknowledged the difference between the disordered and ordered, the experimenter then presented four cartoon drawings of different agents: a teenage girl, a baby, a cat, and an open window (the wind). The experimenter then asked children to identify which agent they thought changed the objects. After the child selected a particular agent, the experimenter subsequently asked children whether any of the other agents were responsible for the change: '*Do you think that any of the other ones could have changed the objects?*'

Two patterns emerged. First, children did not distinguish between different kinds of order and the type of agent responsible, which suggests that knowledge regarding 'an agent's ability to create order' might be stored at a fairly abstract level. Second, older children were significantly more likely than younger children to say that the baby could create different types of order. This finding, that older children were more likely to say that the baby could create order, was quite surprising. When we examined children's justifications (which were coded along a number of dimensions) we found that younger children were reliably more likely to provide

'Physical' justifications, while older children were reliably more likely to provide 'Mental' justifications. Thus, despite a similar response pattern, Kindergarteners and Second-graders seem to causally account for order in very different ways. Such a pattern potentially explains the finding that older children are more likely report that a baby can create order, since they may represent such causal patterns in terms of human mental abilities, which would apply not only to adults but also to infant humans. Such beliefs must then be further revised (to arrive at the adult intuition) as children develop more nuanced appreciations of the ways that intelligence and knowledge change across an organism's life span.

5. How (and Why) is the Order-Agent link Present in Preverbal Infants?

Although preverbal infants are not likely sensitive to all of the subtleties and variation involving intelligent agents and order, they do seem to have robust expectations that agents are uniquely capable of taking a disordered array to a relative state of order. Given these early expectations, the question arises as to how such expectations are cognitively possible in the mind of a preverbal human? Moreover, why might it be important for them to possess such intuitions? Put simply, we see a continuing puzzle with no obvious answer, but in the section below we offer some speculations as to why this knowledge may arise in preverbal infants.

To frame the puzzle, consider again what seems to be needed, psychologically, for infants to have such expectations. First, straightforward perceptual triggers do not seem to be adequate as an apparently enormous range of event configurations that go from disorder to order are likely to elicit expectations of intentional agents. Second, those expectations about agents are in turn highly context sensitive and flexible in terms of what entities are allowed to fill the roles of intentional agents (e.g. an animated ball, a hand, etc.). Third, the expectations may be found as early as around 9 months, but have not yet been shown in the first six months of life. In short, preverbal infants seem to have conceptual expectations about the idea of order in a wide range of instantiations, about a wide range of intentional agents and a potentially causal link between the two. This is in contrast to lower-level perceptual expectations about animacy (which can be triggered by certain bounded motion patterns), chasing (with highly constrained cues) or Newtonian launching (again with well specified cues). If we look at adult reports of the reasoning behind such expectations about ordering and agents, we often find great difficulty in articulating the reasoning; but when it is articulated, it seems surprisingly abstract and complex in ways that are difficult to attribute to young infants.

There are at least three broad classes of psychological accounts of how such expectations emerge in infancy, none of which take us very far in understanding the basis for such expectations. Thus, while the accounts differ significantly from each other, they do not lend much insight into how infants are actually forming their expectations.

First, one might argue that there is simply an innate hard-wired link between the concepts of intentional agents and ordering events. Such an argument is generally appealing to the extent that one can make a case that such a link either has a high adaptive value or is a consequence of another set of innate capacities that do have adaptive value. We consider that issue at the end of this section but note that even if a strong adaptive value story was feasible, it still gives us little insight into mechanism. What does an innate ordering event detector look like at a representational or computational level? Are there any feasible computational accounts that might be informative? For example, there is immense interest in algorithms that can detect new forms of ordered activity among individuals in public spaces as ways of detecting and controlling public demonstrations, terrorism and crime (Sjariff *et al.*, 2012); but to date all of these techniques tend to work on rather disjunctive sets of highly specific patterns, such as rate of walking, accelerations of some walkers toward others, number of individuals within a defined radius, convergence of several individuals on a common target, etc. It is difficult to conceive of an innate pattern detector based on such a disjunctive set of cues.

Second, perhaps infants rapidly learn the causal plausibility and probability of certain events. That is, they learn about the mechanics of simple inanimate objects in a manner that enables them to make judgments about the likelihood of interactions between inanimate entities yielding ordered relations. They might, for example, develop a sense of dispersion and scattering as physically plausible but not of convergence and ordering. Put in contrasting terms, they might learn a set of principles of things that simple bounded inanimate objects cannot do. This isn't much of an explanation, however, because it doesn't provide any details of how such a learning process could work and how an infant could learn and represent principles that were adequate for covering all possible cases of ordering. In addition, to fully account for the findings of all the infant studies, it appears that they would also have to learn general principles governing what intentional agents can do with respect to arranging other objects. Perhaps a simple rule could be that intentional agents could do anything to an array. This is of course not accurate, but it might suffice as a simple rule in infancy. However, even if this simple rule about animates could be easily acquired by preverbal infants, it could not explain why they seem to have such strong expectations that inanimate agents *cannot* create ordered arrays. Insights about both intelligent agents and inanimate objects seem to have to be acquired for a learning account to work.

A third view might claim that infant expectations are made by building up a set of 'brute force' associations between prototypical intentional agents and prototypical events they engage in, and contrasting those to associations about inanimate objects and their prototypical events. Such networks of associations, then, in conjunction with principles for judging similarity between learned prototypes and novel instances, might yield appropriate patterns of infant expectations. Thus, perhaps a typical infant has many observations of adults tidying up messes such as toys, clothing and articles in the kitchen and thereby associates adult human agents with 'tidying' and then that link somehow generalizes to new instances. A comparable set of associations would be learned between inanimate objects and prototypical events such as launching, stopping at a barrier, slowing to a stop on a surface, etc. The problem with such accounts are in the details of what is associated with what and whether any such associations could serve as an adequate platform for novel instances. We frankly don't see a plausible account without strong *a priori* constraints on the kinds of associations that are formed, constraints that take us back to the first view. Even worse, we suspect that some highly atypical events, namely going from one intricate ordered array to a different equally ordered array would be instantly obvious to infants as mediated by intentional agents even though they were quite novel in nature.

In short, it is still a puzzle as to how infant expectations about ordering emerge. It might be argued, however, that whatever the mechanisms are, there are good reasons for them to be present because of the value of 'hyperactive agency detectors' to many organisms. The argument has been made many times in the literature (e.g. Boyer, 1994; Vallortigara, 2012), but we suggest that it has been made primarily for other kinds of events and may not go through nearly as neatly for the ordering events. The most common version of the argument is that there is a huge asymmetry between the low costs of false positives and the high cost of false negatives. For example, it seems far more adaptive to occasionally falsely infer that a rustle in the bushes, a rippling on the water, or a wiggling in the grass is a predator than to falsely discount such indicators when they are in fact legitimate signs of a predator.

But the payoffs are much less clear for detecting the agents behind ordering events. The timing parameters are such that the agent may be long gone by the time its presence is inferred, especially in the case of static arrays. Second, it seems implausible that agents that are scrupulously engaged in ordering the world around them pose the same threats as agents actively in motion near by. We have trouble imaging a real world case where the ability to infer an agent from a recent or ongoing ordering event had important survival value for an organism such that it could directly lead to hyperactive agent detection. It also appears that false positives would exceedingly rare. How often would one notice an ordering event in real time (that is *not* the slow growth of a flower out of a seed) that was not a valid indicator of an intentional agent work? In short, the agent detection system for ordering events appears to have no immediate adaptive value and probably does not exhibit the hyperactivity and false positives of other animacy detection systems and therefore likely works in fundamentally different ways.

A more indirect adaptive argument might be that, while the ability to infer agents behind ordering events has no obvious immediate survival value for infants, it may serve as a necessary building block for later emerging abilities that are essential to humans. Perhaps there is adaptive value to detecting from static ordered arrays the presence of fellow intentional agents either as friends or as enemies but that the only way to build such abilities is by first learning how to detect such agents for real time ordering events. It seems at least plausible that hunter gatherers roaming over large natural spaces might be advantaged by an ability to quickly infer that other humans have been in their vicinity in some recent time period, especially given anthropological work on aggression between small groups of such individuals (Berndt, 1964; Layton, 2014). Or perhaps the ability to reverse-engineer complex systems or design tools depends on a more foundational ability to recognize purpose-driven order. We'll return to these admittedly speculative points in our section on a possible developmental model.

6. Developing the Argument from Design

Our task is to explain how a preverbal infant who infers agents behind real time ordering events develops into an older human who falls prey to the argument from design as a basis for concluding there must be a god. We suspect there are connections here, but that the path takes several steps and is not a path that leads inevitably to the Argument from Design.

In the first few months of life, infants clearly are sensitive to the contrast between social agents and inanimate objects and make a wide range of inferences about the goal driven behaviors of social agents. This partitioning of the world into social and non-social causal entities may then provide critical agent categories for making inferences about ordering events.

At around 8 months of age, infants may be sufficiently adept at encoding events as ordering or disordering sequences that they can consider possible causes of transitions between before and after states. They do so at an earlier age than inferring agents for static ordered displays because the before and after states are so salient for real time events.

It may then be that sufficient experience interpreting real time ordering events enables young children to develop longer and longer time perspectives and start to adopt a 'natural history perspective' on static scenes. That is, they are able to look at an ordered array and work backwards to a prior state because of their experience with witnessing ordering events in the past. They may start to develop a much more intuitive way of thinking about origins of current states and realizing that they did not always exist that way. We don't know how such skills emerge, but we suspect that this happens during the preschool years and may be supported by their emerging autobiographical and narrative skills (Fivush, 2011) that enable them to see the present as one point along a historical time line that also extends into the future.

We therefore predict that by the fourth year of life, and possibly earlier, children become much more inclined to look at present states of affairs and wonder about the historical events that led to the present state. Once that perspective becomes natural for them, it may then launch them into a great deal of learning and inferences about plausible histories, agents and futures. One factor that may become increasingly important in this learning process is a shift from merely seeing things as having functions or affordances to having designed functions (Defeyter and German, 2003). As children come to better appreciate the intentionality and planning latent in many artifacts they may start to appreciate the ever more sophisticated levels of intelligence that agents must have had to be able to construct such artifacts.

In turn, their developing understanding of the intricacies of human cognition with its component processes such as planning, memory and attention may inform their inferences about how agents can create complex order, and designed functions.

It seems clear that by late preschool, most children appreciate that artifacts are created by humans, and they have some sense that more complex artifacts require more intelligent agents. They would know for example that a simple two-dimensional array probably does not require as much agent intelligence as a complex multidimensional hierarchical array. They do not have the same sense of complexity as adults (Kominsky, Zamm and Keil, prep), but they do note differences in behavioral complexity and corresponding differences in the complexity of underlying causes behind those differences (cf. Erb, Buchanan and Sobel, 2013).

We have focused initially on agents and artifacts, but now turn to biological systems. There is now substantial evidence that preschool and elementary school children underestimate, often to a significant degree, the complexity inherent in many biological and psychological systems relative to the complexities of devices, tools and other artifacts (Kominsky, Zamm and Keil, in prep; Keil, Lockhart and Schlegel, 2010). Indeed, only during the later elementary school years do children start to approach adult senses of the relative complexities of such biological organs as the eye in comparison to say, a watch. Thus, your average preschooler does not show amazement at the complexity of the eye, the heart or the kidney while being easily amazed by the complexity of a Rube Goldberg machine at a science museum. It takes time to appreciate the complexity of biological systems and organs and with that appreciation comes a clear sense of functions and often of design. The 'cleverness' of the human eye with such features its adjustable focus lens, its ability to modulate levels of light, and have relatively transparent cells to allow better retinal processing is not apparent to a young child. This may partly because such parts and their functions are not typically as exposed for visual inspection, especially in working order, as they traditionally have been in devices ranging from grandfather clocks to mousetraps (but decreasingly so in our solid state world).

The putative developmental progression of agent detection and agent inference is summarized in Table 1 (here applying just to animate agents).

1. Distinguishing Agents from Inanimate Objects—Rustles, Ripples and Roars.
2. Appreciation of Goal Directed Actions—Reaching, Chasing, Thwarting.
3. Linking of Many Kinds of Ordered and Non-Random Sequences.
4. Appreciating that Only Agents Create Changes in Relative Order for Real Time Events.
5. Plausible Natural Histories—Inferring the Existence of Agents from Static Arrays.
6. Restricting Inferences Based on Physical and Mental Capacities.
7. Functional Design, Complexity, Intelligent Agents—Argument from Design.

Table 1 *Hypothesized Developmental Progression of Agent Detection and Agent Inferences.*

The Argument from Design may only be seductive when there is a sufficient appreciation of biological complexity and the extraordinary extent to which an organ or organism has not only 'climbed Mount Improbable' (Dawkins, 1997), and has acquired not just intricate non-random structures, but ones that seem to be exquisitely tuned to serve specific functions. It may depend critically on simpler earlier emerging sense of agents behind ordering events but it also involves much richer sets of inferences about kinds of complexity, function, purpose and kinds of agency.

We do not think the argument from design is inevitable. Although versions of the argument may be traced back to antiquity, it is an open question as to how common it has been either in history or across cultures. When the Reverend William Paley developed the argument as an enhancement of its version as criticized by Hume, Paley and many others considered it to be an important conceptual advance (Paley, 1867). The argument from design is not simply the same as origin myths, which are widespread across cultures and history. Such myths don't usually run in the direction of making the case for supernatural agents from some aspect of the world's structure. Instead, such agents are often presupposed for other reasons and are used to explain origins of all sorts where reference to design may be minimal. Thus, the idea that there must be an intelligent agent as the cause of certain natural phenomena, most notably those biological phenomena with apparent functional architectures, may be relatively subtle and complex and may not occur to the average layperson without some cultural prompting. The question then remains as to why the argument seems to be irresistible to some once presented.

7. Blocking the Argument from Design Inference

We have suggested that the Argument from Design may not emerge spontaneously and inevitably in most groups but that it may have a certain 'stickiness' because of prior much more powerful tendencies to infer intentional agents as the causes of order. We suggest that such inferences are automatic and nearly inevitable for ordering events. We then argued that the emergence of a natural history perspective extends the inferences about intentional agents to static scenes, perhaps becoming just as automatic and inevitable for children and adults as ordering events are for infants. Thus the 'Goldsworthy effects' (cited in the Introductory section) may, with typical cognitive development during the preschool years, become involuntary inferences as well. But then, things may become more optional as children come to appreciate ever-higher levels of biological complexity and apparent functional design and become susceptible to the Argument from Design.

The question is just *how* susceptible? It may be that, without competing causal belief systems, there is an extremely strong susceptibility, and not just for those with certain personality traits and cognitive styles (Blakemore *et al.* 2003; Shenhav *et al.*, 2012). After all, once one is presented with the argument that a system has a high degree of order and function that seems to have been 'cleverly' designed, it seems close to irrational to deny the workings of an intentional agent. We see several cognitive biases as supporting this susceptibility in all humans: an essentialism about traits that blocks the idea of trans-species change (Hull, 1965), causal biases about how essences must be instantiated (Newman and Keil, 2008), difficulties in thinking of causal paths of populations over time as opposed to individuals; the challenges of thinking of cause in probabilistic as opposed to deterministic terms, and the difficulty of envisioning change over longer time scales as opposed to those that can be directly experienced in a lifetime. In short, there is a convergence of several cognitive biases that make it hard to understand evolution by natural selection, which is presumably why it took so long for the insights of Darwin and Wallace to emerge. When evolution is misunderstood or only partially grasped, it is all too easy to be seduced by the Argument from Design (Dawkins, 2006).

We are unsure about whether any program of general science education will provide a kind of strong immunity from Argument from Design exposure or whether it will always be an alluring explanation even for those who believe they have understood evolutionary theory. But perhaps understanding a bit more about the psychological factors that underlie the development of agency inference from various forms of order will provide as important an inoculation as education in evolution.

Thus, the Argument from Design may depend on these earlier developing cognitive compulsions but it does not seem to be an inevitable consequence. Instead, it may occur when it is suggested by the local culture, or when it cannot be blocked by a more complete understanding of evolutionary theory. The Argument from Design itself appears to be a distorting cognitive bias that may be a legacy of earlier more adaptive biases. However, despite its connections to potentially adaptive primitives, the Argument from Design confers few advantages to adults and potentially large costs. Conceivably, the Argument from Design draws on a more useful adult skill that is needed for reverse-engineering artifacts, but it is not at all clear how widespread such a skill is in the daily lives of most adults, especially in the 21^{st} century.

8. Conclusion

We have argued that the 'cognitive compulsion' to infer intentional agents may appear first for ordering events and then become equally compelling for static scenes. We have further argued that it is a cognitive as opposed to perceptual compulsion given the potentially unbounded perceptual ways that order may be instantiated. The cognitive nature of this compulsion is further supported by the ways in which perceptually atypical agents, such as lamps, can be slotted into an intentional mode of construal. Despite its apparent strength and its early emergence, it is far less clear why such a compulsion should be so foundational and what computational and representational mechanisms support it. Further understanding of its nature may help us understand why it is present even though, with right cultural prompts, it may lead to clearly misleading later arguments for the existence of divine creation.

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Appendix A: Methods and Results for Pendulum Study 1

Participants. Twenty-eight full term 13-month-old infants participated. Fourteen infants (6 girls and 8 boys, mean age = 13 months, 1 day) participated in the Experimental condition, and 14 infants (6 girls and 8 boys, mean age = 13 months, 12 days) participated in the Control condition. Data from an additional 4 infants was discarded because of procedure error (2 infants), or failure to complete study due to inattention and overall fussiness (2 infants). Infants were recruited through the database maintained by the Yale University Infant Cognition Center, and were given a token gift for their participation.

Procedure. Infants sat on their parent's lap, approximately 100 cm from a projection screen that was surrounded with black curtains.

Baseline Trials. Infants' looking was first measured to two still frame shots: one of a hand, and one of a white desk lamp. This was done to determine whether infants had any baseline looking preferences to either of the objects presented during test events. Infants in both conditions saw each still frame once, with the order of presentation counterbalanced across infants.

Familiarization. During familiarization, infants in both conditions were presented with a brief movie (recorded from a live presentation) in which a pendulum (a pink cylinder suspended from a point located just above the top-center of the display) swung back and forth across the display. Each familiarization trial began when the pendulum was released from off-screen and entered the display on the right-hand side. The pendulum swung back and forth across the stage, briefly traveling behind an opaque barrier that was located at the far left-hand side of the stage. This regular harmonic motion continued until the infant looked away from the monitor for 2 consecutive seconds or if 30 seconds elapsed. At the end of each trial, a curtain was briefly lowered and then raised to begin a new trial. Infants in both conditions were exposed to 3 familiarization events.

Test events: Experimental condition. Following habituation, infants saw two different test events, presented in alternating order (see Figure 4). In Animate (hand) test events, the pendulum entered the display from off screen on the right-hand side, as in familiarization. The pendulum continued to swing across the stage until it passed behind the opaque barrier. At this point, however, the motion of the pendulum abruptly stopped (as evidenced by the cessation of motion in the rope). The pendulum remained briefly frozen behind the barrier for approximately 1 second before it was released and swung back toward the right-hand side of the screen. When the pendulum reversed directions and again swung behind the barrier it again stopped and remained frozen there. At this point, the barrier was removed to reveal an experimenter's hand holding the pendulum. The movie then paused with the hand holding the pendulum, and infants' looking-time was recorded.

In Inanimate (lamp) test events, infants were exposed to nearly the identical sequence of events. In fact, the motion of the pendulum was identical to the Animate condition, which was accomplished by splicing the video at a point in which the pendulum was frozen behind the barrier for the second time. Unlike the Animate condition, however, when the barrier was removed, it revealed the cylinder resting inside the lip of the lamp.

Test events: Control condition. The purpose of the control condition was to ensure that infants were not responding based on either superficial properties of the display (i.e. a preference to look longer at either at the lamp or hand), or inferences about the physical affordances of the display—i.e. responses based on the implausibility of the pendulum's ability to fit inside of the lamp. Hence, following familiarization to the same movies as in the Experimental condition, infants in the control condition were presented with test events that pictured only the final end-states: the Animate-Control test event began with the pendulum frozen behind the barrier. The barrier was then removed to reveal a hand holding the pendulum. Similarly, in the Inanimate-Control test event, the barrier was removed to reveal the pendulum resting inside of the lamp. Thus, infants were presented with two seemingly disjointed events: the regular motion of the pendulum in familiarization and the pendulum stationary behind the barrier in test. Critically, these test events lacked the point at which the unseen agent intervened on the motion of the pendulum by causing it to repeatedly stop behind the barrier.

Infants in each condition saw six alternating test events, with order of presentation counterbalanced across infants. A hidden observer, unaware of the order of events, measured looking time on each trial.

Results. Analysis of the baseline trials indicated that overall, infants had a baseline preference to look significantly longer at the hand ($M = 8.15$) than at the lamp ($M = 5.14$), as indicated by a mixed-design ANOVA with condition (Experimental versus Control) as a between-subjects factor and baseline object (hand versus lamp) as a within-subjects factor. This analysis revealed a significant main effect of object type, F (1, 25) = 7.03, $p = .014$; no other main effects or interactions were found.

We next compared Test Event looking times across the two conditions, via a mixed-design ANOVA with condition as a between-subjects factor and test event type (Animate versus Inanimate) as a within-subjects factor. This analysis revealed a significant interaction between experiment and test-event type, $F(1, 26) = 9.67$, $p < .01$. As predicted, infants in the Experimental condition flipped their baseline looking preference to instead look reliably longer at the Inanimate (lamp) outcome ($M = 8.03$ s) compared to the Animate (hand) outcome ($M = 6.15$ s). In contrast, infants in the Control condition looked reliably longer at the Hand-Control ($M = 7.86$ s) compared to the Lamp-Control ($M = 5.49$ s), which was consistent with their baseline preference.

To directly compare infants' pattern of looking in baseline versus test events for each condition, we ran two mixed-design ANOVAs with trial type (baseline versus test) as a between-subjects factor and object type (hand versus lamp) as a within-subjects factor. This analysis revealed a significant interaction between trial type and object type in the Experimental condition, $F(1, 13) = 5.87$, $p < .05$. In contrast, there was only main effect of object type in the Control condition $F(1, 12) = 10.71$, $p < .01$. Further analyses indicated that there were no effects of either sex of infant or order of presentation (both Fs < 1).

Appendix B: Methods and Results for Pendulum Study 2

Methods. This experiment was identical to Experiment 1 except as noted here. Fourteen new infants (7 girls and 7 boys, mean age = 13 months, 2 days) participated in the Luxo condition, and 14 infants (7 girls and 7 boys, mean age = 13 months, 1 day) participated in the Luxo-Control condition. Data from an additional infant was discarded because of procedure error.

At the beginning of each trial, infants in the Luxo condition were shown a brief 30-second computer-animation. The animation was a segment from the short animated film, *Luxo Jr* by Pixar animations, which features a white desk lamp that exhibits several animate cues—e.g. biological motion, contingent action, and goal-directed behavior. After this movie was played once, infants were then presented with the same familiarization and test events as in the Experimental condition of Experiment 1.

Infants in the Luxo-Control condition were exposed to a nearly identical series of events. However, instead of watching the *Luxo Jr* animation, infants in the control condition watched a movie that consisted of a series of still frames taken from the *Luxo Jr* movie. The still frames were presented in a sequence that corresponded to the sequence in the actual *Luxo Jr* movie. To equate for the presence of motion, the still frames in the control movie slowly panned to the left or to the right of the screen, such that the display contained motion, but not biological motion. Hence, all of the stimulus dimensions were equated nearly identically across the Luxo and Luxo-Control movies, with the one critical exception that the Luxo movie clearly portrayed a lamp behaving animately, while the control movie clearly did not. Following the Luxo movie, infants were presented with the same Familiarization and Test movies as in Experiment 1.

Results and Discussion. We compared Test Event looking times across the two conditions, via a mixed-design ANOVA with condition (Luxo versus Luxo-control) as a between-subjects factor and test event type (Animate versus Inanimate) as a within-subjects factor. This analysis revealed a marginal interaction between condition and test-event type, $F(1, 26) = 3.41$, $p = .07$. Consistent with the notion that the animate motion of the Luxo familiarization would now 'prime' infants to think of the lamp as more animate, infants in the Luxo condition looked equally long at the Inanimate (lamp) outcome ($M = 5.64$ s) as they did to the Animate (hand) Outcome ($M = 6.06$ s). In contrast, infants in the Control condition looked significantly longer at the Inanimate-Control ($M = 5.28$ s) compared to the Animate-Control ($M = 4.35$ s), $t(13) = 2.58$, $p < .05$. Further analyses indicated that there were no effects of either sex of infant or order of presentation (both Fs < 1).

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