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Biases towards internal features in infants' reasoning about objects

George E. Newman[1], Patricia Herrmann[2], Karen Wynn[1], Frank C. Keil[1]

[1] Yale University

[2]Northwestern University

Address : George E. Newman
Department of Psychology
Yale University
New Haven, CT 06520
Phone : (203) 436 1414
Fax : (203) 432 7172
Email : george.newman@yale.edu

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Abstract

This paper reports the results of two sets of studies demonstrating 14-month-olds' tendency to associate an object's behavior with internal, rather than external features. In Experiment 1 infants were familiarized to two animated cats that each exhibited a different style of self-generated motion. Infants then saw a novel individual that had an internal feature (stomach color) similar to one cat, but an external feature (hat color) similar to the other. Infants looked reliably longer when the individual's motion was congruent with the hat than when it was congruent with the stomach. Using a converging method involving object choice, Experiment 2 found that infants prioritized the internal feature over the external feature only when the object's behavior was self-generated. In the absence of self-generated behaviors, infants did not show a preference towards the internal feature.

The same objects can be evaluated in very different ways, and our ability to make accurate inferences about them depends precisely on the type of information that we consider. For example, if we want to know whether a cat has an owner we might check to see if it has a collar. In contrast, if we want to know whether the cat is good at catching mice we might consider deeper factors, such as its ferociousness or genetic make-up. Often, such inferences – especially those that consider the role of deeper, unseen factors -- exploit rich clusters of causal knowledge or "intuitive theories" (Murphy & Medin, 1985); and a great deal of work in psychology has examined how children and adults utilize such knowledge in making different types of inductive generalizations.

In this paper, we focus on one specific knowledge cluster -- namely, the importance of internal features for inferences about an object's behavior. As in previous work, we define internal features as features that are physically behind or under an object's outer layer (e.g., S. Gelman & Wellman, 1991). In contrast, external features are features that are outside, or part of, an object's exterior. Previous work suggests that children as young as four readily distinguish between internal and external features (S. Gelman, 2003; Simons & Keil, 1995). Moreover, they appreciate that internal features are vital to how an animal moves and behaves (S. Gelman & Kremer, 1991; S. Gelman & Gottfried, 1996; S. Gelman & Wellman, 1991; R. Gelman, Durginm & Kaufman, 1995; Opfer & Gelman, 2001). For example, preschoolers are likely to report that internal features are responsible for making birds be able to fly, or if that you remove a dog's inside stuff it is no longer capable of barking or eating dog food (S. Gelman & Wellman, 1991). Importantly, children do not see such properties as emanating from external features, such as whether or not a dog has fur (*ibid*).

In the present study we sought to test whether similar types of appreciations may also be present in infancy. Indeed, there is evidence to suggest that infants are capable of prioritizing certain types of features over others in their understanding of objects. For example, in the now classic "drinking and driving" studies, Mandler and McDonough (1996) demonstrated that 14-month-old infants generalize 'drinking from a cup' to animals and 'giving a ride' to vehicles on the basis of differences in category, not surface similarity. Similarly, 14- and 18-month-old infants will focus on object function when categorizing novel artifacts (Booth & Waxman, 2002). And, in certain circumstances, 14-month-olds will form categories on the basis of shared internal features (Welder & Graham, 2006). Thus, by 14 months of age, infants seem to have some assumptions about what types of properties may be more relevant in their assessments of objects.

Here we explore whether 14-month-old infants are more likely to associate an object's self-generated behaviors with internal, rather than external features. Experiment 1 used preferential looking time measures to test whether infants prioritize internal features over external features when learning an association between feature color and a particular type of motion. Experiment 2 used a converging method of object choice to ask whether infants prioritize internal features *only* when those features are a potential cause of the object's behavior (i.e., the behavior is self-generated). In the absence of such a connection, we predict that infants should not show a preference towards internal features.

Experiment 1

In Experiment 1 we tested the hypothesis that 14-month-old infants would be more likely to associate an object's specific type of motion with internal, rather than external features. Infants were initially exposed to brief computer-animated events featuring two different cats. The two cats were identical in appearance except that one had a blue stomach and blue hat, while the other had a red stomach and red hat. Both the stomachs and hats were visible. However, the stomachs were positioned inside of the cat's bodies and were permanently connected to them, while the hats were external and were shown to be detachable at the beginning of the trial. During familiarization events, each of the cats exhibited a different 'style' of self-generated motion. The blue cat swayed back and forth, while the red cat jumped up and down.

In test events, infants were presented with a novel cat that had a stomach color similar to one cat, but a hat color similar to the other. Half the infants saw a cat that had a blue stomach and a red hat, while half saw a cat that had a red stomach and a blue hat. In alternating test trials, the cat's motion alternately aligned with either its stomach color or its hat color. We hypothesized that infants should associate the particular type of motion more strongly with the internal feature then with the external feature -- thus, infants in both test groups should look reliably longer when the style of motion is congruent with the hat, then when it is congruent with the stomach.

An additional control condition was included to ensure that infants were attending to the two different types of motions (jumping and swaying) and could correctly attribute them to two different individuals.

Method

Participants

Twenty-eight 14-month-old infants (18 male, 10 female) participated. Sixteen infants with a mean age of 14 months 15 days (range: 13;26 to 15;1) were randomly assigned to the experimental condition. Twelve infants with a mean age of 14 months 17 days (range: 14;5 to 15;3) were randomly assigned to the control condition. An additional 8 infants were tested but were excluded because of fussiness (5), or disinterest (3).

Materials and procedure

Experimental Condition. Infants were seated on their parents' laps, approximately 60 cm from a computer monitor. At the beginning of each experimental session, infants were presented with a familiarization event that was played three times (see Figure 1). In familiarization trials, infants initially saw one cat with a blue stomach (located on the left side of the screen) and a second cat with a red stomach (located on the right side of the screen) – the cats' faces were drawn at the horizontal midpoint of the screen. The cats were identical except for the color of their stomachs; and the bodies of the cats were semi-translucent, so that the stomachs appeared inside of the cats' bodies. After a brief pause (1 s), two hats dropped down from the top of the screen. A red hat dropped onto the red cat's head and a blue hat dropped onto the blue cat's head. The hats were already in motion once they entered the display and moved at a constant rate until they reached the cats' heads. The hats were identical in shape and size to the stomachs. Infants then saw events in which each of the cats alternately exhibited a different style of motion. The blue cat moved by swaying back and forth two times. Each swaying motion took approximately 1 s, and was paired with a "*swish*" sound. In contrast, the red cat moved by jumping up and down two times. Each jumping motion took approximately 1 s, and was paired with a "*boing*" sound. The hats and stomachs also flashed congruently with the cats' motion so as to draw infants' attention. The alternating sequence of jumping and swaying played continuously until the infant looked away from the monitor for 2 consecutive seconds or if 30 s elapsed.

Infants were then presented with two different test events featuring a novel cat, centrally located on the screen. Half the infants saw a novel cat that had a red stomach and blue hat, while the other half saw a cat with a blue stomach and red hat. In test events the cat started the trial wearing the hat such that both the hat and stomach were present throughout the entire duration of the test event. In Stomach Congruent test events the novel cat moved (and made sound) in a manner congruent with the stomach color. For example, the blue stomach/red hat cat swayed back and forth. In Hat Congruent test events the novel cat moved (and made sound) in a manner congruent with the hat color. For example, the blue stomach/red hat cat jumped up and down. For the cat with the red stomach and blue hat the same motions were used, however, now the Stomach Congruent motion was jumping while the Hat Congruent motion was swaying. These events were each presented three times in alternating order, with order counterbalanced across subjects.

Looking time was measured by an observer who was hidden behind a curtain and was unaware of the infant's test group (i.e., blue stomach/red hat vs. red stomach/blue hat). Timing began at the start of each trial, when the test movie first began playing and continued until the infant looked away from the monitor for 2 consecutive seconds or if 30 s elapsed. To be included in the final analyses, infants had to see at least two complete pairs of test events. A test trial was considered complete if the infant watched for at least 2 s (the length of time it took for the individual to display two complete movements). Four subjects in the experimental condition completed the first two pairs of test trials, but not the third. Incomplete trial pairs were discarded from the final analysis. A second experimenter also reviewed video footage from five of the infants and measured their looking times to familiarization and test events. These times were found to correspond well to the on-line timing (r = .99; Mean difference between the two coders = .73 s, SE = .23 s), and thus all data analyses were performed using results from the on-line timing.

Control condition. To ascertain that infants were indeed able to encode the two different types of motion we also ran a control condition. Infants in the control condition were tested with a violation-of-expectation procedure in which no familiarization event was presented. Infants in this condition saw two different types of test events: Same Motion test events and Different motion test events. Both test events began in the same way. The cat with the blue stomach and blue hat was positioned on the left side of the screen, while the cat with the red stomach and red hat was positioned on the right side of the screen. Both the hats and stomachs were present at the beginning of the trial.

Initially, the blue cat swayed and the red cat jumped in an identical manner to familiarization events of the experimental condition. Then, after two alternating sequences of swaying and jumping, the cats switched positions. The blue cat traveled to the right side of the screen and the red cat traveled to the left side of the screen. At this point, the two types of events differed. In Same Motion test events, each of the cats moved in the same way as it had in previous sequences -- the blue cat swayed once and the red cat jumped once. In Different Motion test events, each of the cats exhibited the other's style of motion -- the blue cat jumped once, and the red cat swayed once. The order in which each of the cats moved after they switched positions was counterbalanced across subjects. These events were each presented three times in alternating order, with order counterbalanced across subjects.

Procedures for recording looking time were identical to the experimental condition, except for as follows: timing began after the entire sequence of events had completed (approximately 13 s), and in order for infants' data to be included in the final analyses, they has to watch the entire sequence of events. Three subjects in the control condition completed the first two pairs of test trials, but not the third. A second experimenter also reviewed video footage from four of the infants and measured their looking time. These times were found to correspond well to the on-line timing (r = .98; Mean difference = .27 s; SE = .34 s), and thus all data analyses were performed using results from the on-line timing.

Results

Control Condition. Results from the control condition confirmed that infants attended to the two different types of motion, and were able to associate them with two different individuals. As predicted, this group of infants looked reliably longer at Different Motion test events (M =11.1 s, SE = .52) compared to Same Motion test events (M = 7.5 s, SE = .52). This difference was confirmed by a mixed-design ANOVA with test event-type (Same Motion vs. Different Motion) as a within-subjects factor and presentation order as a between-subjects factor. This analysis revealed no effect of presentation order ($F < 1$), but a significant main effect of test event-type, F (1, 10) = 12.87, $p < .01$. A preliminary ANOVA indicated no effect of test pair order, so this factor was not included in subsequent analyses. A nonparametric analysis was also conducted: Ten of 12 infants looked longer when the cats switched their motion midway through the trial than when they maintained the same motion throughout the trial (p = .04, via a binomial test).

Experimental condition. Test event looking times from this experiment are depicted in Figure 2. The mean duration of infants' looking during the three familiarization events was 25.9 s, 23.8 s, and 22.6 s, respectively. In test events, infants looked reliably longer at Hat Congruent test events (M = 16.4 s, SE = .47) compared to Stomach Congruent test events (M = 13.5 s, SE = .47). This difference was confirmed by a mixed-design ANOVA with Test event type (Stomach vs. Hat) as a within-subjects factor and cat type (red stomach/blue hat vs. blue stomach/red hat) and presentation order as between-subjects factors. This analysis revealed no effect of presentation order or cat type (both Fs < 1), but a significant main effect of test event type, F (1,

12) = 9.31, p = .01. Thus, infants who saw test events involving the red stomach/blue hat cat looked longer at that cat swaying than at that cat jumping (Mean difference = 2.6 s). In contrast, infants who saw test events involving the blue stomach/red hat cat showed the opposite pattern: they looked longer at that cat jumping than at that cat swaying (Mean difference = 3.2 s). An additional analysis with test pair order as a factor revealed a main effect test pair order, F (1, 11) = 10.21, $p < .01$; infants looked longer during the first pair (M = 19.1 s) of test events than during the last pair of test events (M = 9.5 s). Findings were also significant non-parametrically: 13 of 16 infants looked longer when the motion was congruent with the hat color than when it was congruent with the stomach color (p = .02, via a binomial test).

Discussion

The results of this experiment were consistent with the hypothesis that infants should prioritize internal features over external features when learning the relationship between feature color and a particular style of self-generated motion. As predicted, infants looked reliably longer when a novel individual moved congruently with its external feature, than when it moved congruently with its internal feature. This pattern was consistent across both test groups (blue stomach/red hat vs. red stomach/blue hat), where the "unexpected" motion was the opposite in each case. Moreover, results from the control help to establish that infants could distinguish between the two different types of motion and could associate them with two different individuals.

We hypothesize that the most salient difference between the features in this study was that one was internal, while the other was external; and that this factor best explains the observed looking time difference across test events. At the same time, in order to convey to infants that one feature was internal while the other was external, several additional factors were necessarily introduced into the display: the hat was briefly detached at the beginning of the event, the stomach was drawn inside of the cat, and it was located in the center of the body. It is possible that these additional factors could have contributed to infants' looking time preference in test events. However, these alternatives seem less plausible for at least two reasons. First, none of them make clear *a priori* predictions about infants' pattern of looking. For instance, the motion of the hats in the beginning of the display could have drawn infants' attention more to the hats than to the stomachs, but this would actually predict the opposite pattern of results. Moreover, it is not entirely clear that these additional factors are necessarily confounds. In the real world, these same factors (internal central location; being inseparable from the body) are highly correlated with the concept of an internal feature (e.g., a car engine, or a heart) – thus, such spatiotemporal or location cues may often provide critical information about internal features, especially in novel contexts.

Nevertheless, it is important to provide additional evidence that may help to rule out such alternatives. Here the context in which internal vs. external features are evaluated seems highly relevant. If, for instance, we were to view an object that displays clearly self-generated behaviors, then as adults, we would readily assume that internal features must be responsible since they are the only plausible candidates for the behavior. If, however, the context is more ambiguous – for instance, the object does not exhibit any self-generated behaviors -- then we would have no basis to suspect that the internal features play any significant role. Such patterns are not unique to animals. For example, we might comment on a friend's lovely decorative sculpture only to realize that it is actually an oddly shaped stereo speaker. In these different contexts (i.e., viewing an object as a piece of art vs. a complex artifact) we may draw radically different assumptions about the importance of the object's internal features. Such distinctions not only help to differentiate when we may, or may not bias internal features; but if an identical object is presented in both contexts, then it may also serve to rule out the role of any additional factors which could focus attention to internal, rather than external features (e.g., location, etc.). Thus, in Experiment 2, we used precisely this contrast to extend the findings of Experiment 1.

Experiment 2

The aim of Experiment 2 was to explore the conditions under which 14-month-olds prioritize internal features over external ones. We hypothesized that when an object displays self-generated behaviors (e.g., motion and sound) infants should attend to internal features more strongly than when no information is given about the role of the insides. In this study, we presented 14-month-old infants with an actual object (a translucent, animal-like toy with eyes and ears). Inside the object, a white opaque box was visible. On the outside, the top of the object's head was painted with a large green marking that resembled hair. Thus, unlike Experiment 1, the internal and external features were both permanently connected to the individual.

Infants were randomly assigned to one of two different conditions. In one condition, infants saw the object move autonomously and make noise. In the other condition, the object moved in the same way, but through external means (it was shaken by the experimenter). After the object was shown to move either autonomously or via external means, it was removed and infants in both conditions were then presented with the choice of two new objects. One object had the same internal feature but lacked the external marking, while the other object had the same external marking but lacked the internal feature. We predicted that the presence of self-generated behaviors (motion and sound) would encourage infants to focus on the importance of the internal feature. Thus, when given the choice of which object they would prefer to play with, infants should be more likely to select the object with the same internal feature over the object with the same external feature. In contrast, when the self-generated behaviors were not present, we predicted that infants should have no reason to focus on one feature over the other; thus, they should choose randomly between the two objects.

Method

Participants

Twenty 14-month-old infants (12 male, 8 female) with a mean age of 14 months 16 days (range: 13;26 to 15;1) participated. Half the infants were assigned to an experimental condition and half were assigned to a control condition. An additional 6 infants were tested but excluded because of failure to approach the objects (see the next section). Fourteen infants also participated in either the experimental ($n = 9$) or control condition ($n = 5$) of Experiment 1.

Infants always completed the looking-time task (Experiment 1) before the object-choice task (Experiment 2).

Materials and Procedure

Experimental condition. The infant, parent, and experimenter were all seated on the floor. Infants were seated on the parent's lap, approximately 1.5 m away from the experimenter. Parents were first instructed to hold their infant and keep them on their lap. They were also instructed to look down at their infant's back throughout and not to interfere by pointing or tapping. The experimenter then removed a toy from behind her back. In both conditions the toy was a clear, plastic animal-like object with eyes and ears (measuring approximately 11 cm long by 11 cm wide by 11cm deep). Inside the toy, a white opaque box was visible. On the outside, the top half of the toy's head was painted with a large green marking, resembling hair. For infants in the experimental condition, the toy was shown to be capable of two self-generated behaviors (moving autonomously and making sound). As the experimenter placed the toy in front of the infant, she surreptitiously pushed a button on the toy, which caused it to shake and make a "cooing" noise for approximately 4 s. The experimenter waited for approximately 5 seconds and then once again pushed the button on the toy, causing it to shake and coo. The mechanism that was responsible for the motion and sound was contained within the opaque white box such that the "insides" did not move independently from the object while the it was in motion. The experimenter then offered the toy to the infant. Once the infant showed interest in the toy by reaching for it or picking it up, the experiment then removed the toy and placed it out of sight.

The experimenter then brought out two new toys from behind her back. She simultaneously placed the two new toys to her left and right, approximately 1 m to either side, midway between herself and the infant. These toys were each identical to the original except for the absence of one feature. The Same Inside toy was identical to the original, except that it was missing the large green marking on the top the head. The Same Outside toy was identical to the original, except that it was missing the white box on the inside (for a detailed comparison of the objects see Figure 3). After placing the toys to her left and right (with side of presentation counterbalanced across subjects), the experimenter instructed the parent to let the infant approach the toys. The trial ended when the infant walked or crawled to one of the toys and touched it, which was coded on-line by the experimenter. If the infant failed to approach either of the toys within approximately 60 sec., the trial ended and no choice data was obtained.

Control condition. Infants in the control condition were presented with the identical toys and procedure as infants in the experimental condition. However, the original toy did not exhibit the self-generated behaviors. To control for the amount of time that the experimenter interacted with the toy and the extent of motion, when the experimenter first presented the original toy, she shook it for 4 s before placing it in front of the infant. After waiting for approximately 5 s, the experimenter picked up the toy again and shook it for another 4 s. The experimenter then offered the object to the infant and waited until the infant showed interest in the toy before removing it and placing it out of sight.

As in the experimental condition, the experimenter then removed the two new toys (the Same Inside and Same Outside toys) from behind her back and placed them to her left and right, approximately 1 m to either side, midway between herself and the infant. The experimenter instructed the parent to release the infant, and infants were allowed to approach one of the toys. As in the experimental condition, infants' selection of a toy was coded on-line as whichever one they touched first. Here we predicted that because infants did not witness the self-generated motion and sound, they should have no reason to select the Same Inside toy more often than the Same Outside toy – thus, they should choose randomly between the two objects.

Results

A Fisher's exact test with condition (experimental vs. control) and object choice (Same Inside vs. Same Outside) as factors revealed a significant interaction between condition and object choice, $p < .01$. Infants in the experimental condition reliably chose the toy with the Same Inside more often (n = 10 out of 10; $p = .002$, via a binomial test). However, infants in the control condition showed a different pattern of response: only 3 out of 10 infants chose the Same Inside toy, while 7 out of 10 chose the Same Outside toy (this pattern was not statistically different from chance, $p = .34$, via a binomial test).

Discussion

This pattern of results was consistent with the hypothesized outcomes. When the original toy exhibited self-generated behaviors (motion and sound), infants were more likely to choose the object with the same internal feature. However, when self-generated behaviors were not observed and the experimenter merely shook the toy, infants chose randomly between the two test objects. The difference between the experimental and control conditions is critical because it excludes the possibility that infants chose the toy with the Same Inside simply because it was more interesting. Moreover, results from the control condition help to rule out the possibility that infants have a uniform bias towards centrally located features (cf. Experiment 1).

General Discussion

Here we tested the hypothesis that in certain circumstances infants may bias internal features over external ones in their assessments of an object's behavior. Experiment 1 contrasted an internal feature that was part of the same physical object (a stomach) with an external feature that was only superficially attached (a hat). Here, infants prioritized the internal feature over the external feature when predicting how a novel individual would move: infants expected a novel object to move in a way that matched the stomach and not the hat. However, this looking time pattern may have been confounded as the internal feature was attached, while the external feature was not; and the internal feature was centrally located, while the external feature was off-center. Thus, we conducted a second study involving object choice, where both the internal and external features were attached, and varied whether or not the internal feature had a potential role in self-generated behaviors. In this case, infants prioritized the internal feature *only* when the object's behavior was self-generated, and thus, was a potential cause of the object's motion and sound. When the object moved in a similar manner through external means, infants showed no bias towards the internal feature. Thus, results from Experiment 2 confirmed that infants do not have a general preference for centrally located features. Together, the findings from these two studies suggest that by 14 months of age, infants will bias internal features in their assessments of an object's behavior, and that they may be selective in when they show such biases – e.g., when the behavior appears self-generated.

However, these data do not suggest that infants possess an awareness of *why* internal features may be more important in a given context. In fact, preschoolers' understanding of internal features is often thought to consist of only a vague notion of cause, sometimes referred to as a sort of "placeholder" (S. Gelman, 2003; Iganaki & Hatano, 2002; Keil, 1989). And it may not be until much later in development when children develop specific causal models that link internal features to the relevant types of properties (see Carey, 1985; Keil, 1989). Instead, we propose that somewhere above the level of purely tracking statistical regularities, but below the level of explicit causal theories, infants may be subject to cognitive constraints that prioritize certain, select features over others in specific kinds of contexts. For inferences relevant to self-generated behaviors this may include prioritizing internal features over external features (as in the present studies). As another example, a similar kind of constraint may include prioritizing goal-directed reaches selectively for human hands or animate entities (e.g., Leslie, 1984; Woodward, 1998); or selectively attending to the gaze of animates (Johnson, Slaughter, & Carey, 1998).

Such constraints may lead infants to selectively track some features over others in a given context, which in turn strengthens some feature associations and not others. Over time, such a pattern may begin to shift infants towards larger groupings of features and causal networks in the development of more elaborate knowledge clusters (see Tenenbaum, Kemp, & Shafto, in press, for similar proposals and computational models). Thus, we suggest that infants may use biases towards internal features (along with other similar sorts of constraints) to 'bootstrap' more complicated sets of appreciations about their world. Future research should explore the scope of such constraints (e.g., whether they are domain-general or domainspecific), as well as how such constraints might interact in the development of more elaborate causal theories.

References

Booth, A. E., & Waxman, S. R. (2002). Object names and object functions serve as cues to categories for infants. *Developmental Psychology*, *38*, 948–957.

Carey, S. (1985). *Conceptual Change in Childhood*. Cambridge, MA: MIT Press.

Gelman, R., Durgin, F., & Kaufman, L. (1995). Distinguishing between animates and inanimates: Not by motion alone. In D. Sperber, D. Premack, and A. Premack, (Eds.), *Causal cognition: A multidisciplinary debate* (pp. 150-184). Oxford: Clarendon Press.

Gelman, S. A. (2003). *The essential child: Origins of essentialism in everyday thought*. Oxford: Oxford University Press.

Gelman, S. A., & Gottfried, G. M. (1996). Children's causal explanations for animate and inanimate motion. *Child Development, 67*, 1970-1987.

Gelman, S. A., & Kremer, K. E. (1991). Understanding natural cause: Children's explanations of how objects and their properties originate. *Child Development*, *62*, 396-414.

Gelman, S. A., & Wellman, H. M. (1991). Insides and essence: Early understandings of the non-obvious. *Cognition*, *38*, 213–244.

Johnson, S. C., Slaughter, V., & Carey, S. (1998). Whose gaze will infants follow? Features that elicit gaze-following in 12-month-olds. *Developmental Science*, *1*, 233-238.

Keil, F. C., (1989). *Concepts, kinds, and cognitive development.* Cambridge, MA: MIT Press.

Leslie, A. (1984). Infant perception of a manual pick-up event. *British Journal of Developmental Psychology*, *2*, 19-32.

Mandler, J. M., & McDonough, L. (1996). Drinking and driving don't mix: Inductive generalization in infancy. *Cognition*, *59*, 307–335.

Murphy, G. L., & Medin, D. L. (1985). The role of theories in conceptual coherence. *Psychological Review. 92*, 289-316.

Opfer, J. E., & Gelman, S. A. (2001). Children's and adult's models for predicting teleological action: The development of a biology-based model. *Child Development, 72*, 1367-1381.

Simons, D. J., & Keil, F. C. (1995). An abstract to concrete shift in the development of biological thought: The insides story. *Cognition, 56,* 129-163.

Tenenbaum, J. B., Kemp, C., and Shafto, P. (in press). Theory-based Bayesian models of inductive reasoning. To appear in Feeney, A. & Heit, E. (Eds.), *Inductive reasoning*. Cambridge University Press.

Welder, A. N., & Graham, S. A. (2006). Infants' categorization of novel objects with more or less obvious features. *Cognitive Psychology*, *52,* 57-91.

Woodward, A., (1998). Infants selectively encode the goal object of an actor's reach, *Cognition*, *69*, 1-34.

Author Note

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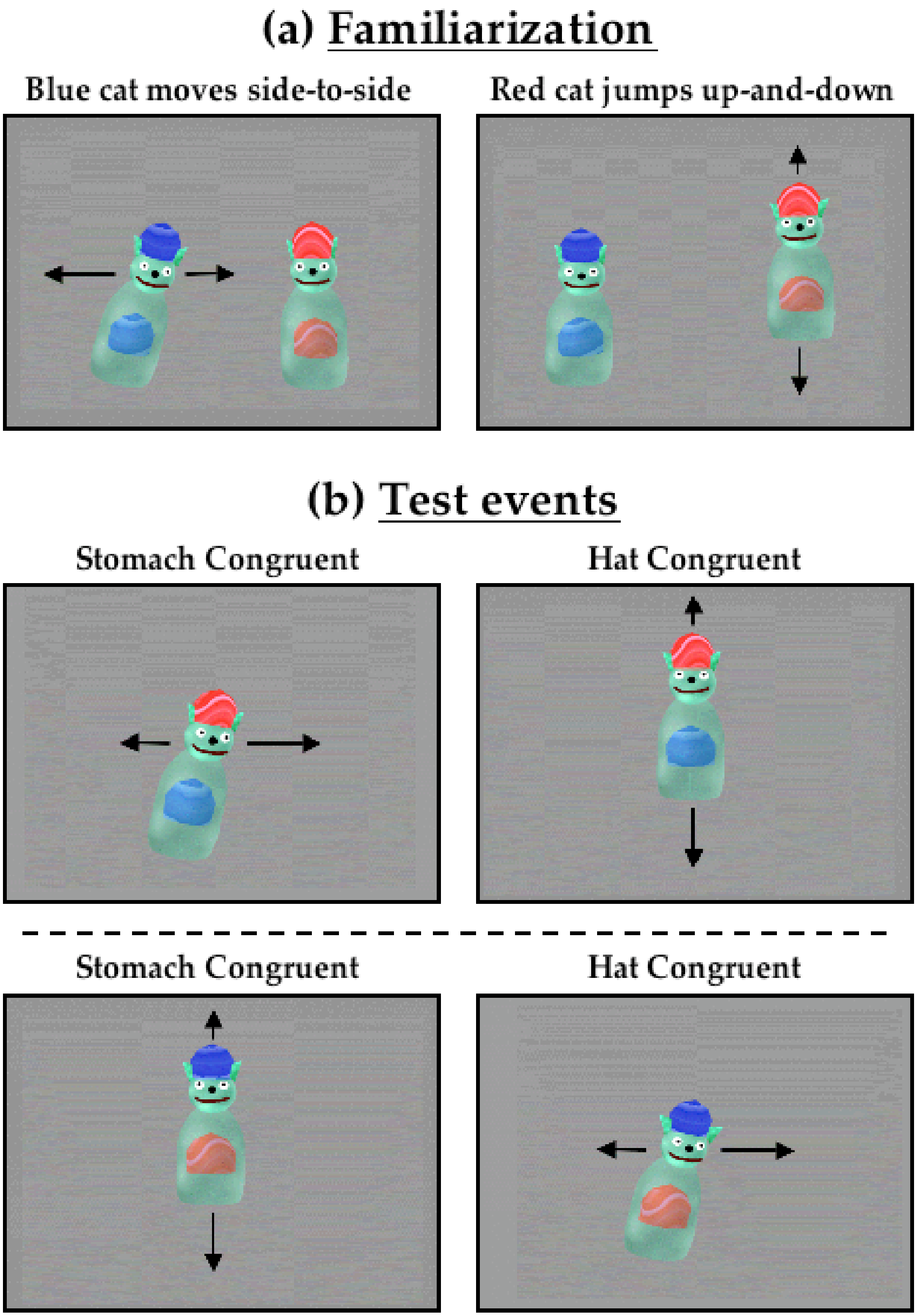
Figure Captions

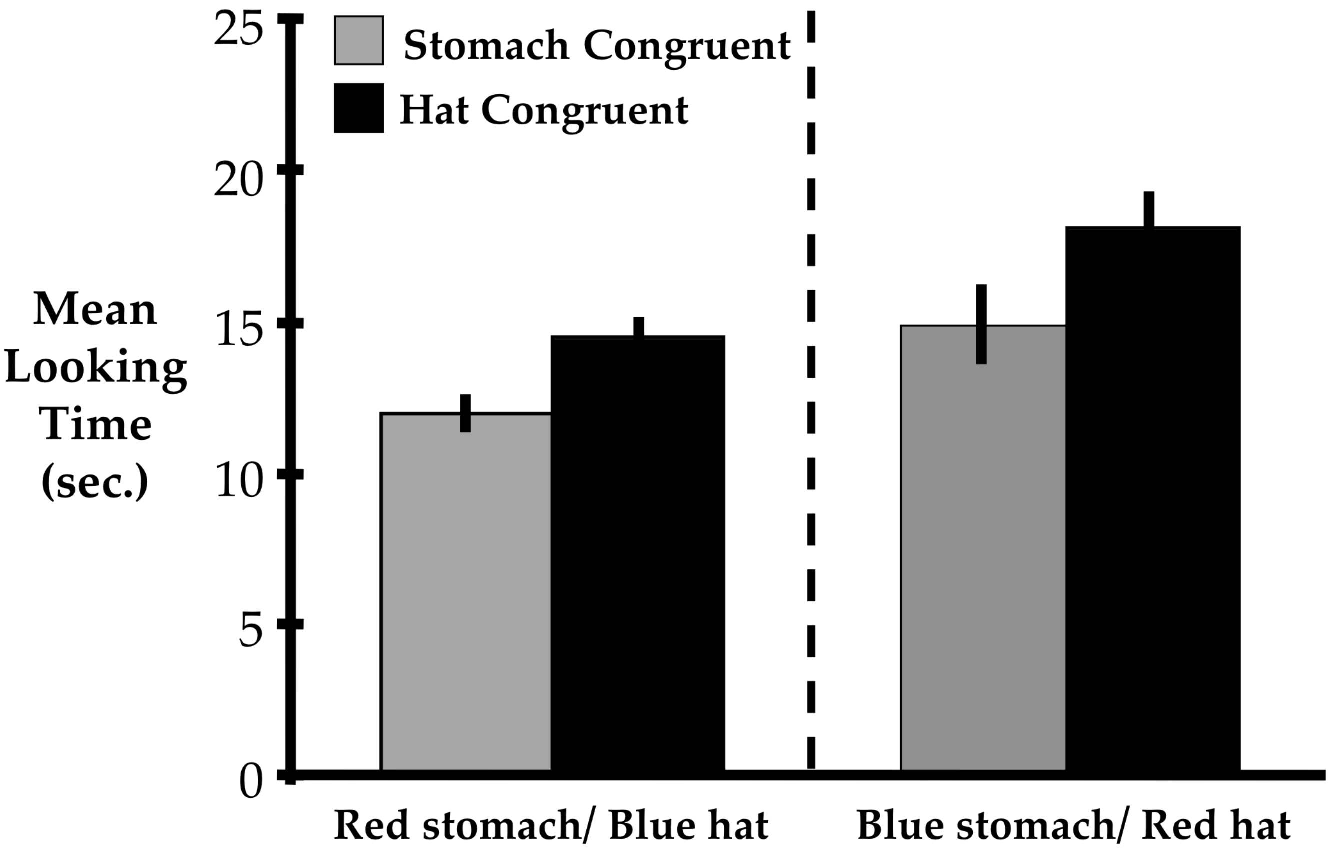
Figure 1. Experiment 1 (Experimental condition). (a) Depiction of the events presented to infants during familiarization. Arrows indicate motion. Infants were familiarized to the blue cat swaying back and forth and the red cat jumping up and down. (b) Depiction of the events presented to infants during test events. Half the infants were shown events involving a cat with a blue stomach and red hat, while half were shown events involving a cat with a red stomach and blue hat. In Stomach Congruent test events the cat's motion was congruent with its stomach color (if blue, swaying; if red, jumping). In Hat Congruent test event the cat's motion was congruent with its hat color.

Figure 2. Duration of looking time (+/- *SE*) to each test event type as a function of which feature combination infants were presented with. For the cat with the red stomach and blue hat, the Hat Congruent motion was swaying, while for the cat with the blue stomach and red hat, the Hat Congruent motion was Jumping.

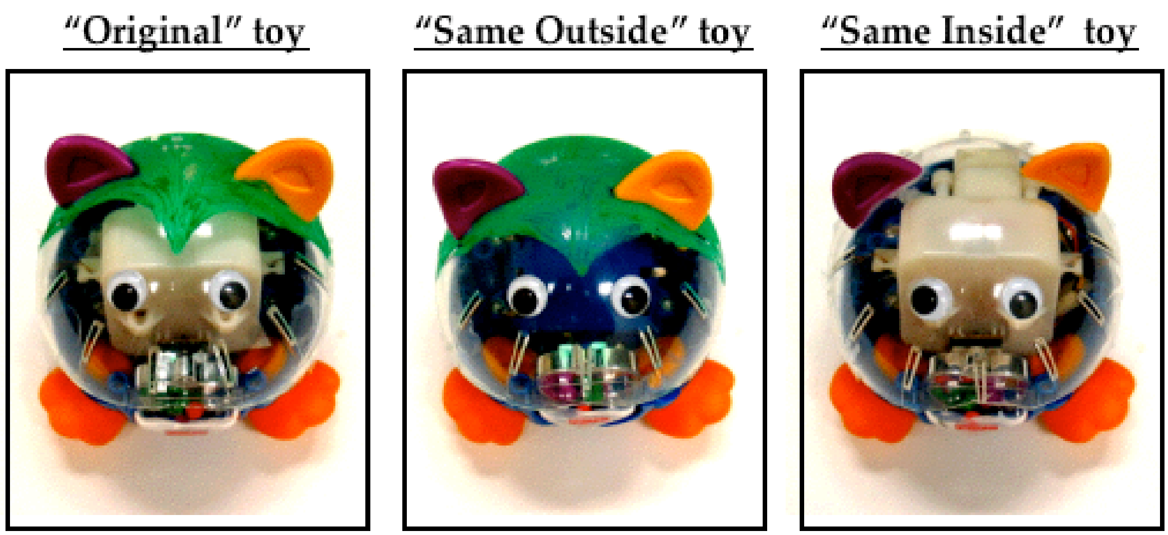
Figure 3. Photographs of the objects presented to infants in Experiment 2.


(a) Familiarization
Blue cat moves side-to-side
Red cat jumps up-and-down
(b) Test events
Stomach Congruent
Hat Congruent
Stomach Congruent
Hat Congruent

(Figure 1)


25
20
15
10
5
0
Stomach Congruent
Hat Congruent
Mean Looking Time (sec.)
Red stomach/ Blue hat
Blue stomach/ Red hat

(Figure 2)



(Figure 3)