Research Report

Familiarity Breeds Searching
Infants Reverse Their Novelty Preferences When Reaching for Hidden Objects

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ABSTRACT--What infants appear to know depends heavily on how they are tested. For example, infants seem to understand object permanence (that objects continue to exist when no longer perceptible) within the first few months of life when this understanding is assessed through looking measures, but not until several months later when it is assessed through search measures. One explanation of such results is that infants gradually develop stronger representations of objects through experience, and that stronger representations are required for some tasks than for others. The current study confirms one prediction from this account: Stronger representations of familiar objects (relative to novel objects) should support greater sensitivity to their continued existence. After seeing objects hidden, infants reached more for familiar than novel objects, in striking contrast to their robust novelty preferences with visible objects. Theoretical implications concerning the origins of knowledge are discussed.

Fundamental debates in the study of cognitive development concern the origins of knowledge. Scientists continue to grapple with even basic questions in this domain, because different lines of evidence support divergent interpretations. One example concerns the origins of knowledge about object permanence, or the understanding that objects continue to exist when no longer perceptible. Infants demonstrate sensitivity to object permanence at quite different ages depending on how the concept is measured. Infants as young as 2.5 months look longer at impossible events with hidden objects (e.g., one object seems to pass through the space occupied by a second, hidden object) than at possible events (Spelke, Breinlinger, Macomber, & Jacobson, 1992). Yet infants fail to search for objects hidden in the dark until they are several months older (Goubet & Clifton, 1998; Hood & Willatts, 1986) and search for objects hidden by covers later still (Piaget, 1954; Shinskey & Munakata, 2003). Explaining why infants exhibit such behavioral dissociations in different tasks ostensibly measuring the same concept may critically inform debates surrounding the origins of knowledge.

One explanation for such dissociations suggests that infants gradually develop stronger mental representations of objects through experience, with stronger representations required for some tasks than for others (Munakata, McClelland, Johnson, & Siegler, 1997). Weak representations of a hidden object may support 2.5-month-olds' sensitivity to violations of its permanence, but stronger representations may be necessary to drive 5- to 7-month-olds' manual search in the dark, and even more robust representations to drive 8- to 10-month-olds' search when confronting a visible barrier. According to this graded-representations account and related perspectives, representations of hidden objects may strengthen gradually with experience perceiving and interacting with objects (Fischer & Bidell, 1991; Haith & Benson, 1997; Piaget, 1954). Repeated exposures to a stimulus can produce changes in the patterns of neural activity representing that stimulus, as demonstrated in single-cell recording studies with nonhuman primates (Miller & Desimone, 1994), electrophysiological studies with humans (Curran, 2000), and artificial neural network models (Munakata et al., 1997). Such changes from repeated exposures could strengthen representations of familiar objects, so that these representations can be maintained when the objects are hidden, supporting a developing sensitivity to the continued existence of hidden objects (Munakata et al., 1997). One prediction from this perspective is that infants' sensitivity to object permanence may be greater with familiar objects than with novel objects.

The current study tested this prediction: If infants have stronger representations for familiar than for novel objects, and if these stronger representations support greater sensitivity to the continued existence of the objects when hidden, infants should search more for familiar hidden objects than for novel hidden objects.[1] This prediction may be counterintuitive, because infants typically display robust preferences for novelty over familiarity when stimuli are perceptible, as demonstrated across countless experiments on perception (Fantz, 1964), memory (Diamond, 1995), language (Saffran, Aslin, & Newport, 1996), categorization (Quinn & Eimas, 1996), and number (Lipton & Spelke, 2003). Novelty preferences reflect the efficiency of immature organisms' information processing: Once infants have mastered all the information one stimulus offers, attending to a new stimulus is an adaptive strategy for acquiring large amounts of information in a short time. Indeed, lack of novelty preference in infancy predicts cognitive delays in childhood (Rose & Feldman, 1995). Thus, the natural prediction is that infants should show novelty preferences with both visible and hidden objects. (Infants sometimes show familiarity preferences under limited circumstances not relevant to the present study, a point we return to in the Discussion.) In contrast, we predicted that robust novelty preferences with visible objects would reverse to familiarity preferences with hidden objects. Stronger representations of familiar objects should lead to less interest in them when visible (and more exploration of novel objects), but greater sensitivity to their continued existence when they are hidden (and less exploration of novel objects).

METHOD

Twenty-four full-term 7-month-olds participated (range: 7 months 1 day-7 months 21 days; M = 7 months 10 days; 12 girls). Fifteen additional infants participated but were excluded because of fussiness (9), experimenter error (3), equipment failure (1), parental interference (1), and difficulty reaching for visible objects (1).

Infants were presented with one object at a time, familiar or novel, under visible or hidden conditions. Stimuli consisted of clay objects differing in shape and color and were designed to reduce the risk that infants would have inherent preferences among them. To equate for attractiveness, we counterbalanced the object designated familiar across infants.

We hid objects using darkness, as in previous studies (Goubet & Clifton, 1998; Hood & Willatts, 1986), to minimize motor and problem-solving demands and to equate reaching demands for visible and hidden objects. A video camera equipped with infrared light for taping in the dark recorded infants from above. Strips of glow-in-the-dark tape flanked the search space to orient infants in the dark without revealing the object.

The procedure began with six 7-s trials of familiarization with the dark, followed by a familiarization phase in which we presented infants with the same object on repeated trials during which they were allowed 7 s to reach. Familiarization ended when the infant stopped reaching for the object on 2 consecutive trials or reached for a maximum 24 trials (M = 14, SE = 1.44). Each infant then received 16 test trials, 4 trials each of four events: familiar-visible, novel-visible, familiar-hidden, and novel-hidden (see Fig. 1). The familiar-visible event was identical to familiarization trials: We presented the familiar object on each trial and allowed the infant 7s to reach. The novel-visible event was identical to the familiar-visible event except that a different novel object was presented on each trial. Familiar-hidden and novel-hidden events were identical to familiar-visible and novel-visible events, respectively, except that after infants fixated the object, we hid the object in the dark by turning off the light, and a different set of novel objects was used for the novel-hidden events. The four trials for each event were blocked together, with blocks presented in one of eight counterbalanced orders.

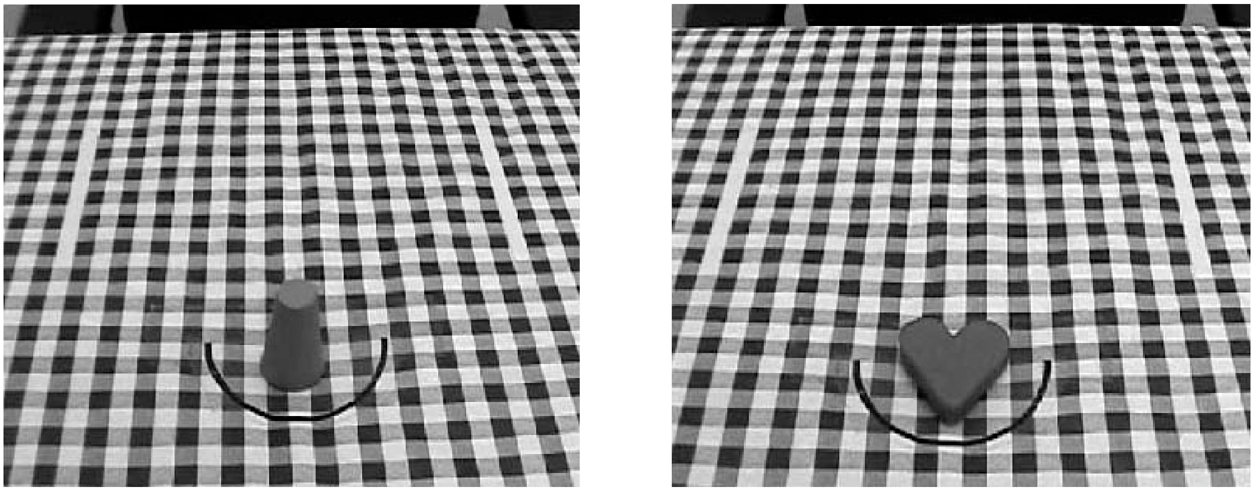
On familiarization and test trials, a reach was scored if the infant's hand crossed into the half-circle (10-cm diameter) surrounding the object and was less than 9 cm above the table. These criteria helped equate the reaching demands for visible and hidden objects, and allowed infants to reach without a precise object grasp. Because the experimenter could not see the infant's behavior in the dark, an observer watched the session on a monitor from a lightproof booth in the room, signaling the experimenter with a beeping sound over an earphone when the infant reached. To prevent the infant from executing a reach in the dark that he or she had planned in the light, the experimenter instructed the parent to restrain the infant's hands, ensured that the infant fixated the object, turned the light off, waited 1 s, and then tapped the parent's foot as the signal to release the infant's hands. To equate hidden and visible trials, the experimenter signaled the parent 1 s after ensuring the infant fixated the object on the visible trials.

In addition to the primary coder, two secondary coders who were blind to the study hypotheses scored nonoverlapping halves of the data. Reliability between the primary coder and the blind coders was 98.44% (agreement on 378 out of 384 trials).

RESULTS

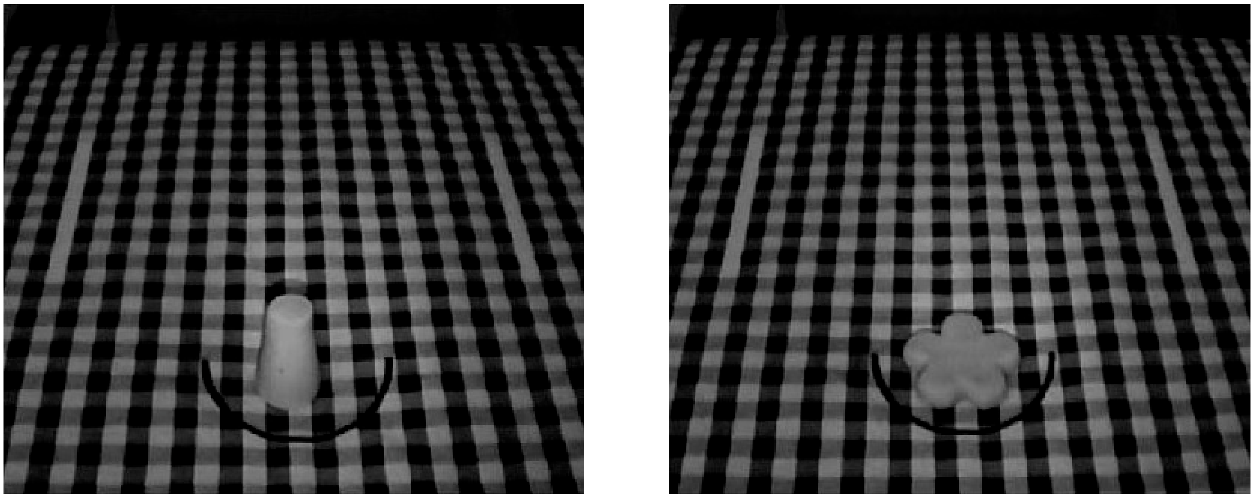
As predicted, when objects were visible, infants reached more for novel objects than for the familiar object, but when objects were hidden, they reversed this strong novelty preference by reaching more for the familiar object than for novel objects. Analysis of variance yielded a significant interaction of visibility with familiarity, $F(1, 23) = 51.33$, $p < .001$, $\eta_p^2 = .69$.[2] When objects were visible, infants reached for a novel object on 88% ($SE = 5\%$) of trials and for the familiar object on 39% ($SE = 6\%$) of trials, $t(23) = 7.83$, $p < .001$, $d = 1.88$. In contrast, when objects were hidden, infants reached for a novel object on only 20% ($SE = 5\%$) of trials and for the familiar object on 32% ($SE = 7\%$) of trials, $t(23) = -2.97$, $p < .01$, $d = 0.48$. Nonparametric analyses revealed a similar pattern (see Fig. 2a for the numbers of infants showing a novelty preference vs. a familiarity preference). On visible trials, 20 infants reached more for novel objects than for the familiar object, whereas none reached more for the familiar object, and 4 reached equally for the two kinds of objects, Wilcoxon $Z = -3.98$, $p < .001$. In contrast, on hidden trials, only 3 infants reached more for novel objects than for the familiar object, whereas 13 reached more for the familiar object, and 8 reached equally for the two kinds of objects, Wilcoxon $Z = -2.56$, $p < .05$. Of these latter 8 infants, 7 failed to reach at all, rather than reaching indiscriminately.

Results were also consistent with object representations strengthening with experience in that the effect increased over trials, as indicated by a three-way interaction of visibility, familiarity, and trial (1 vs. 4), $\_^2(1, N = 24) = 17.04$, $p < .0001$. This effect was driven by changes across trials with the familiar object only (Fig. 2b). Reaching for the familiar object increased across trials when it was hidden, $\_^2(1, N = 24) = 5.54$, $p < .05$, but showed a trend to decrease across trials when it was visible, $\_^2(1, N = 24) = 3.14$, $p = .076$. In contrast, reaching for novel objects did not change.



Familiar-Visible

Novel-Visible



Familiar-Hidden

Novel-Hidden

Fig. 1. Examples of the four test events. Hidden events are illustrated using infrared photography but were completely dark from the infant's perspective, except for the glow-in-the-dark strips on the sides. The black half-circle on the table was used by coders to score reaches.

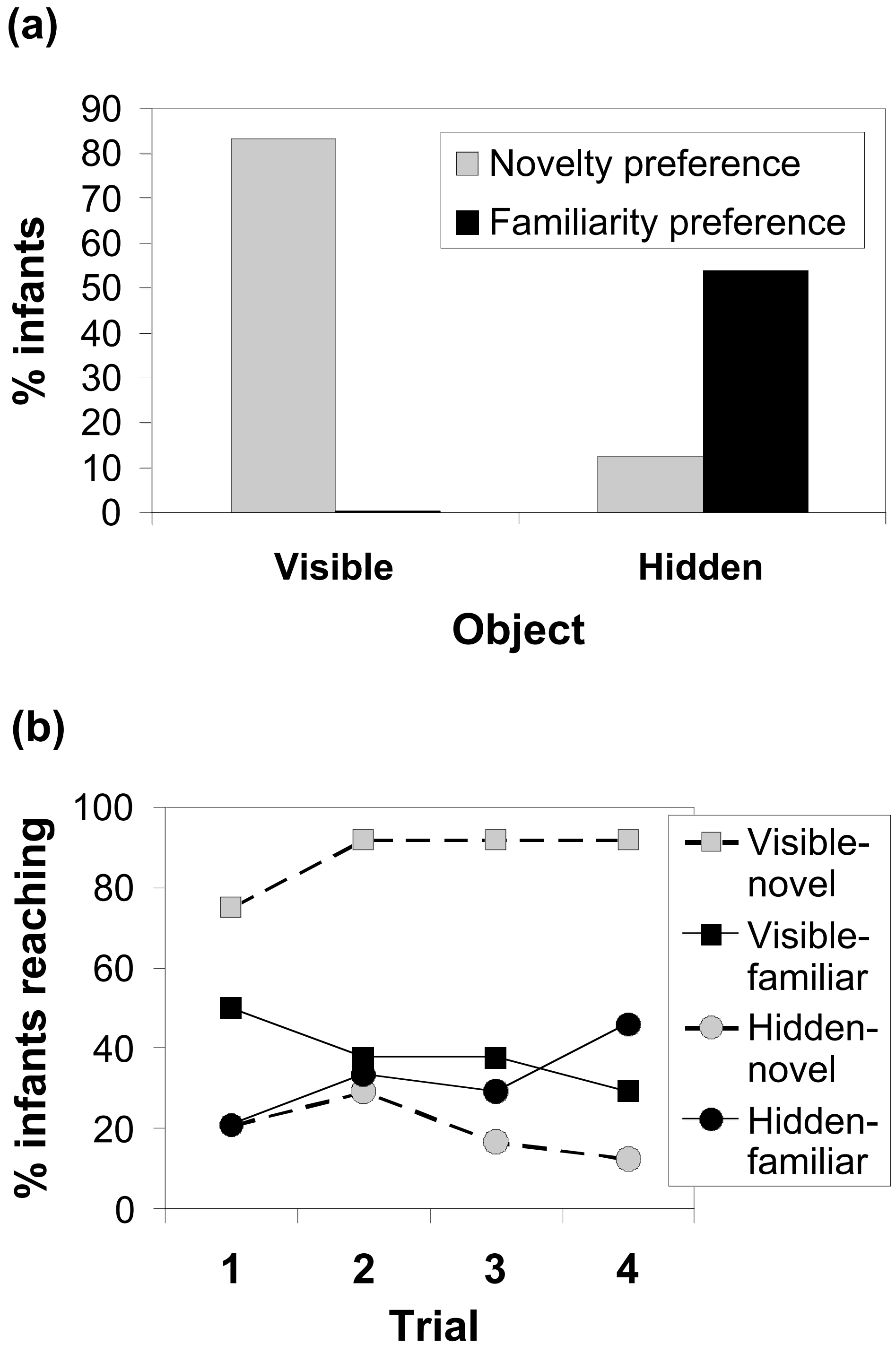


Fig. 2. Infants' reaching for novel and familiar objects, when visible and hidden. The graphs show the percentage of infants exhibiting novelty and familiarity preferences (a) and the percentage of infants reaching for the object as a function of trial number (b).

DISCUSSION

As predicted, when objects were hidden, infants reached more for a familiar object than for novel objects, in direct contrast to their novelty preference with visible objects. This is the first demonstration of its kind. Although infants in other studies have displayed familiarity preferences with visible stimuli under certain circumstances, these results reflect insufficient processing of the familiar stimulus because of infants' age, stimulus complexity, or limited familiarization time (Hunter & Ames, 1988; Meltzoff & Borton, 1979). In contrast, in the current study, infants' strong novelty preference with visible objects demonstrated that the infants processed the familiar object sufficiently. Yet they still reached more for the familiar object than for novel objects when objects were hidden. Stronger representations of familiar objects (relative to novel objects) can thus lead to reduced exploration when they are visible, but greater exploration when they are hidden.

Changes in representations can occur with even relatively brief experiences. In the present experiment, reaching for the familiar object more than doubled across trials when it was hidden, but tended to decrease across trials when it was visible (whereas reaching for novel objects did not change). This pattern suggests that the representation of the familiar object strengthened over only four trials in one experimental session. Likewise, in previous research, merely 2 min of experience tracking a visible moving object enhanced 4-month-olds' anticipations of the object's reappearance when its trajectory was briefly occluded (Johnson, Amso, & Slemmer, 2003).

These results inform several perspectives on the origins of physical knowledge. According to the graded-representations account motivating this study, learning from repeated exposures to stimuli may strengthen the ability to represent hidden objects’ continued existence. Weak representations of hidden objects may suffice for some tasks but not others, leading to the behavioral dissociations observed across development. From this perspective, understanding of concepts such as object permanence may originate in learning from specific experiences. Such learning may begin with familiar objects, only later generalizing to all objects. Neural network models have demonstrated how such generalization processes may rely on neural regions (e.g., prefrontal cortex) with computational processes distinct from those of other regions for processing specific objects (Rougier, Noelle, Braver, Cohen, & O'Reilly, 2005). This graded-representations perspective complements a shift in the study of some areas of cognitive development toward a focus on the remarkable specificity of infants' knowledge (e.g., Baillargeon, 2004) and the effects of specific experiences on learning (e.g., Thelen & Smith, 1994).

In contrast, some researchers posit that initial knowledge takes the form of abstract principles that may be innate (e.g., Marcus, 1998; Spelke et al., 1992). From this perspective, behaviors inconsistent with abstract principles (e.g., looking-reaching dissociations) reflect performance factors rather than competence. For example, infants might have a concept of object permanence but fail to reach for hidden objects because of deficits in problem-solving skills (e.g., removing a barrier to obtain an object; Diamond, 1991). Or infants might have a concept of object permanence but not remember novel objects as well as familiar objects. Studies show that some potential performance factors do not fully explain infants' behavior (e.g., Shinskey & Munakata, 2001), but additional performance factors could be posited to explain behaviors appearing inconsistent with abstract principles. However, the growing number of performance factors reduces the explanatory power of abstract-principles accounts. In addition, apparent changes in performance factors can actually emerge from changes in knowledge representations (MacDonald & Christiansen, 2002; Munakata et al., 1997).

A more recent treatment of cognitive development focuses on cognitive load; infants' failures on various tasks may reflect their limited resources being overloaded by processing demands, from actions and physical reasoning (Boudreau & Bushnell, 2000; Keen, Carrico, Sylvia, & Berthier, 2003). Infants may succeed in looking tasks earlier than reaching tasks because of differences in action complexity. Or, when objects are hidden, infants may reach more for familiar than novel objects because representing novel objects requires more cognitive effort. From this perspective, infants fail not because they lack problem-solving skills or understanding of object permanence, but because when either problem solving or object representation becomes difficult, the other suffers. Some forms of the cognitive-load account may be compatible with abstract-principles approaches, for example, if cognitive load is viewed as a performance factor preventing infants from revealing underlying competence. Other forms of the cognitive-load account may be compatible with the graded-representations account, for example, if remembering novel objects is more effortful than remembering familiar objects because of the nature of the representations of those objects.

Further specifying and differentiating such possibilities will be an important step in understanding why infants' apparent knowledge varies so greatly depending on the testing method. The current findings provide an important constraint in this process: As infants begin searching when objects are hidden, they demonstrate greater sensitivity to the continued existence of familiar objects than novel objects, despite robust novelty preferences when objects are visible. Reconciling such variations in infant sensitivity should ultimately inform fundamental questions concerning the origins of knowledge.

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[1] Previous studies manipulated object familiarity in search tasks (e.g., Jackson, Campos, & Fischer, 1978; Legerstee, 1994), but the results are difficult to interpret. First, stimuli were not equated for factors such as attractiveness and emotional significance (e.g., familiar stimuli were objects or people from home, whereas novel stimuli were objects or people from the lab). Second, results were collapsed across different events, with objects that were fully hidden, partly visible, or fully visible, and with silent and sounding objects. Thus, these studies do not address whether novelty and familiarity preferences differ depending on object visibility.

[2] These proportional data were corrected with arcsine transformation to satisfy the assumption of homogeneity. Analysis of variance also yielded main effects revealing that infants reached more for visible (M = 87%, SE = 7%) than hidden (M = 31%, SE = 8%) objects, $F(1, 23) = 22.00$, $p < .001$, $\eta_p^2 = .49$, and more for novel (M = 74%, SE = 5%) than familiar (M = 43%, SE = 5%) objects, $F(1, 23) = 37.46$, $p < .001$, $\eta_p^2 = .62$.