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Something old, something new: a developmental transition from familiarity to novelty preferences with hidden objects

Jeanne L. Shinskey[1] and **Yuko Munakata**[2]

[1]Department of Psychology, Royal Holloway, University of London, UK and Department of Psychology, University of South Carolina, USA

[2]Department of Psychology, University of Colorado, Boulder, USA

Abstract

Novelty seeking is viewed as adaptive, and novelty preferences in infancy predict cognitive performance into adulthood. Yet 7-month-olds prefer familiar stimuli to novel ones when searching for hidden objects, in contrast to their strong novelty preferences with visible objects (Shinskey & Munakata, 2005). According to a graded representations perspective on object knowledge, infants gradually develop stronger object representations through experience, such that representations of familiar objects can be better maintained, supporting greater search than with novel objects. Object representations should strengthen with further development to allow older infants to shift from familiarity to novelty preferences with hidden objects. The current study tested this prediction by presenting 24 11-month-olds with novel and familiar objects that were sometimes visible and sometimes hidden. Unlike 7-month-olds, 11-month-olds showed novelty preferences with both visible and hidden objects. This developmental shift from familiarity to novelty preference with hidden objects parallels one that infants show months earlier with perceptible stimuli, but the two transitions may reflect different underlying mechanisms. The current findings suggest both change and continuity in the adaptive development of object representations and associated cognitive processes.

Introduction

From pigs to primates, many mammalian species exhibit a strong propensity to explore novel stimuli more than familiar stimuli, particularly in their infancy (e.g. Brown, Almond & Bates, 2005; Wood-Gush & Vestergaard, 1991). Novelty seeking is adaptive because it enhances immature mammals' abilities to construct knowledge about their environments (e.g. Gibson, 1988). Human infants likewise typically exhibit robust preferences for novelty relative to familiarity with visual displays. For example, in paired-comparison tasks when infants have a choice between looking at a familiar pattern with which they have been habituated or a novel pattern, the majority of infants spend more time fixating the novel pattern (e.g. Fantz, 1964). Such exploration of novel information is predictive of how well individuals adapt to their environments across development. For example, high novelty preference during infancy predicts high scores later in childhood on tests of intelligence, language, memory, and speed of information processing (e.g. Rose, Feldman & Jankowski, 2004). Conversely, either a familiarity preference or no preference between novel and familiar stimuli during infancy is predictive of cognitive impairment later in development (e.g. McCall & Carriger, 1993).

Address for correspondence: Jeanne L. Shinskey, Department of Psychology, Royal Holloway, University of London, Egham, Surrey TW20 0EX, UK; jeanne.shinskey@rhul.ac.uk.

Novelty preferences during infancy predict individual differences in cognitive performance into adulthood as well, at least to age 21 (e.g. Fagan, Holland & Wheeler, 2007). This stability over time suggests continuity in information-processing abilities over development, supported by mechanisms that are common to species-typical cognitive processes throughout the life span (Bornstein, Hahn, Bell, Haynes, Slater, Golding & Wolke, 2006).

Nevertheless, infants can also exhibit familiarity preferences under several circumstances. For example, they are more likely to prefer familiar stimuli earlier in infancy than later, when they have had insufficient or interrupted familiarization, when the stimuli are complex rather than simple, and when the task involves cross-modal transfer of information (Houston-Price & Nakai, 2004; Hunter & Ames, 1988; Roder, Bushnell & Sasseville, 2000; Streri & Ferón, 2005). One common factor among these circumstances may be a weak or incomplete representation of the familiar stimulus that promotes further visual processing of it until the infant's representation is sufficiently strong to move on to processing another, novel stimulus (Rose, Gottfried, Melloy-Carminer & Bridger, 1982). Young infants may thus show familiarity preferences because they need to dwell on a visual stimulus to form a sufficiently strong representation of it, while improvements in speed of processing allow older infants to more rapidly obtain information and move on to processing a novel stimulus (e.g. Rose, Jankowski & Feldman, 2002). In this way, preferences for novel or familiar stimuli can reveal developments in the strength of underlying representations and associated cognitive processes.

This same approach has been used to investigate developments in infants' understanding of the concept of object permanence - that objects exist independently of perception (Piaget, 1954). According to a graded representations account and related perspectives, infants gradually develop stronger object representations through experience (Fischer & Bidell, 1991; Haith & Benson, 1998; Mareschal, 2000; Munakata, McClelland, Johnson & Siegler, 1997). One prediction from this account and an associated model (Munakata *et al*., 1997) is that infants should develop strong representations of familiar objects before they develop equivalently strong representations of novel objects, and should thus represent the continued existence of a hidden object earlier when it is familiar than when it is novel. Specifically, repeated exposure should strengthen the representation of a familiar object to allow the infant to maintain the representation when the familiar object becomes hidden. Infants should thus show a familiarity preference with hidden objects, even though they typically prefer novelty to familiarity when objects are visible. This prediction was confirmed in 7-month-olds with manual search. When objects were hidden, infants searched more for a familiar object than a novel one, but when objects were visible, infants showed the expected novelty preference by reaching more for a novel object than a familiar one (Shinskey & Munakata, 2005). This pattern suggests that 7-month-olds' representation of the familiar object was strong enough to support search when it was hidden. In contrast, representations of novel objects were too weak to support search when they were hidden. Thus, consistent with other results showing that familiarity preferences can be adaptive, object representations appear to strengthen with experience to generate less exploration of a familiar object when it is visible but greater exploration of a familiar object when it is hidden.

How do these familiarity preferences with hidden objects change or show stability across development? Understanding the developmental trajectory of such preferences should inform an understanding of developments in the strength of underlying representations and associated cognitive processes (e.g. Kagan, 2008; Quinn, 2008). Although well-established transitions from familiarity preferences to novelty preferences with perceptible stimuli suggest improvements in infants' ability to compare percepts with internal representations, developmental progressions in infants' preferences with objects in the absence of perceptual support have yet to be tested. If older infants shift to novelty preferences with hidden objects, like 2- to 4-month-olds do with visible objects under many circumstances (e.g. Bahrick,

Hernandez-Reif & Pickens, 1997; Rose *et al*., 1982), this would suggest that infants continue to develop stronger representations of hidden objects over time (e.g. Mareschal, 2000; Munakata *et al*., 1997), such that representations and preferences with hidden objects come to resemble those with visible objects. With such developments, representations of both familiar and novel hidden objects would be sufficiently strong to support manual search, just as representations of both familiar and novel visible objects are sufficiently strong to support reaching, but weaker representations of novel objects would support greater exploration of them.

Alternatively, older infants might show familiarity preferences with hidden objects like 7-month-olds do (Shinskey & Munakata, 2005). This pattern would suggest that with development, representations of familiar objects continue to be more likely to be sufficiently strong to support manual search, relative to representations of novel objects. This pattern would be consistent with core knowledge perspectives on the development of object knowledge (e.g. Spelke & Kinzler, 2007), in which infants' object knowledge is characterized by the same domain-specific core principles (e.g. of continuity and cohesion; Spelke, 1994, and persistence; Baillargeon, 2008) as adults' object knowledge.

No studies have directly tested continuity versus change in familiarity preferences with hidden objects. Four studies have yielded suggestive, but inconsistent, results. Whereas some studies suggest that infants may have greater familiarity preferences with hidden stimuli earlier in infancy but less so later in infancy (e.g. Jackson, Campos & Fischer, 1978; Legerstee, 1994; Lingle & Lingle, 1981), others contradict this suggestion (e.g. Tardona & Bradley-Johnson, 1984). Interpreting these inconsistent results is difficult for several reasons. In some cases, results were collapsed over age and over search for partially visible objects and completely hidden objects, potentially masking continuities or discontinuities from one age to another as well as different behaviors when objects were visible versus hidden. For example, infants in several studies (Jackson *et al*., 1978; Lingle & Lingle, 1981; Tardona & Bradley-Johnson, 1984) received the Uzgiris-Hunt Scale of Object Permanence (1975) which consists of 15 search tasks that increase in difficulty. Because the first task consists of partially hiding the object and the second consists of hiding the object after the infant has begun to reach for it, infants might reach more for a novel object than a familiar one as they typically do when objects are visible. In the remaining tasks which all require reaching after the object becomes fully hidden, however, younger infants might search more for a familiar object than a novel one whereas older infants might do the reverse. Collapsing the results across such tasks and ages could result in novelty preference on some tasks or at some ages cancelling out familiarity preference on other tasks or at other ages. Moreover, the novel object was presented repeatedly in several studies (Jackson *et al*., 1978; Legerstee, 1994; Lingle & Lingle, 1981), rendering it relatively more familiar at the end of the study than at the beginning, which could obscure potential differences in behavior with the 'novel' object versus the familiar one. In other cases, novel and familiar stimuli included people (e.g. Legerstee, 1994; Jackson *et al*., 1978), which may introduce factors such as stranger anxiety (with a novel person) or attachment (with a familiar person) that have different effects on infants' motivation to search at different ages.

The current study addresses these limitations to directly test whether familiarity preferences for hidden objects are continuous or discontinuous over development, as a window onto developments in infants' object representations and associated cognitive processes. Although transitions in preferences with visible objects are well established, fundamental questions about the continuity of object representations in the absence of perceptual support remain unanswered. We presented 11-month-olds with the same events as the 7-month-olds in Shinskey and Munakata's (2005) study. The methods were designed to avoid the limitations in previous work, such as collapsing results across different ages or visibility conditions, presenting a novel object repeatedly, comparing search for objects versus people, and including

auditory cues. Infants received repeated trials on which either a familiar object or a novel object either became hidden or remained visible. Objects were hidden by darkness to equate reaching demands for obtaining visible and hidden objects as in Shinskey and Munakata (2005). This method also minimizes motor and problem-solving demands, which was important for 7-month-olds in the original study. If infants develop stronger representations of hidden objects across this period, such that representations of both novel and familiar objects are sufficiently strong to support manual search, then 11-month-olds should show a novelty preference whether objects are visible or hidden, unlike 7-month-olds. In contrast, if representations of familiar objects continue to be more likely to be sufficiently strong to support manual search, then 11-month-olds should show a familiarity preference for hidden objects in contrast to their novelty preference for visible objects, like 7-month-olds.

Method

Participants

Participants included 24 full-term infants (12 girls) with a mean age of 10 months 30 days (range 10 months 21 days to 11 months 6 days). Nineteen additional participants were excluded from the sample due to fussiness (10), equipment failure (3), parental interference (3), experimenter error (2), and fixation with the glow-in-the-dark tape flanking the search space (1). Participants were recruited from birth records through a letter sent to parents in the mail shortly after birth and a subsequent telephone call. Parents received $5 travel compensation and infants received a small gift for participating.

Apparatus and stimuli

The apparatus and stimuli were identical to those used with 7-month-old infants in Shinskey and Munakata (2005), with the exception that the search space was moved 3 cm back from the front edge of the table (from 15 to 18 cm) to accommodate the older infants' greater reach span. Participants were tested at a table in a room blocked from external light and lit by a 40-watt floor lamp. Infants sat on the parent's lap across the table from the experimenter, who presented the events, timed them with a metronome that beeped once per s through an earpiece, and operated the lamp with a foot switch. A video camera equipped with infrared light for taping in the dark recorded the infant from above. The camera projected to a monitor in a light-proof booth within the room, where an observer indicated to the experimenter over an earphone whether the infant reached in the dark. The monitor's screen was marked with the search space, a half-circle (10 cm diameter) surrounding the object. To orient infants in the darkness, the search space was flanked by two strips of glow-in-the-dark adhesive tape (1 × 15 cm), placed 29 cm apart and 30 cm back from the front edge of the table. Stimuli consisted of 15 clay objects differing in shape and color, designed to reduce the risk that infants would have inherent preferences among them. Objects consisted of simple shapes (e.g. cube, cylinder, ring) ranging in length from 3.5 to 9.5 cm, in width from 3.5 to 8 cm, and in height from 1.5 to 5.5 cm.

Design

The primary factors in the current design were the within-participants variables of Visibility (visible or hidden) and Familiarity (novel or familiar). The current data from 11-month-olds were also compared with the prior data from 7-month-olds using the between-participants factor of Age. Trials of the same event were presented in blocks of four for a total of 16 trials: Familiar-Visible, Novel-Visible, Familiar-Hidden, and Novel-Hidden (Figure 1). Events were presented in eight different orders, counterbalanced between participants. For each infant, each familiar trial presented the same familiar object whereas each novel trial introduced a unique novel object. To equate for attractiveness, the object designated familiar was counterbalanced across participants.

Procedure

The procedure was identical to that used previously with 7-month-olds in Shinskey and Munakata (2005), except that the search time was reduced from 7 to 5 s to accommodate older infants' more mature reaching ability. The procedure began with a dark familiarization phase, to accustom infants to the darkness. Using the foot switch, the experimenter turned off the floor lamp for 10 s, during which time the only visible items were the strips of glow-in-the-dark tape on the table. Trials were repeated for a total of six trials of darkness.

An object familiarization phase followed, in which the infant was presented repeatedly with one object. Each trial began with the parent gently restraining the infant's arms while the experimenter placed the object on the table and ensured the infant fixated it. After 1 s, the experimenter tapped the parent's foot under the table as the signal to release the infant's arms. A reach was scored if the infant's hand crossed into the search space and was less than 9 cm above the table. This criterion helped equate the reaching demands for obtaining visible and hidden objects, and allowed infants to reach without a precise object grasp. Familiarization trials were repeated with the same object until the infant stopped reaching on two consecutive trials or reached for a maximum 24 trials (M = 14.5, SE = 1.3).

The test phase consisted of blocks of trials in which a single object was presented on each trial for the following events: Familiar-Visible, Novel-Visible, Familiar-Hidden, and Novel-Hidden. Each trial began with the parent gently restraining the infant's arms to prevent the infant from reaching before the object became hidden. The experimenter then placed the object in the center of the search space, ensured the infant fixated it, waited 1 s, and then signaled the parent with a foot tap to release the infant's arms. On half the trials, the object was familiar and on half it was novel, with a different novel object on each trial. On half the trials, the object remained visible and on half it became hidden by darkness, when the experimenter turned off the light 1 s before signaling the parent to release the infant's arms. The 1-s delay was designed to ensure that infants did not simply execute a reach in the dark that they had planned while the object was still visible in the light, but instead reached on the basis of their representation of the object while it was hidden. The 1-s delay was equated for visible and hidden trials. Infants had 5 s to reach for an object and reaches were scored as in the object familiarization phase.

Two coders, one of whom was blind to the experiment hypotheses, scored all of the data. Reliability between the coders was 99.5% (agreement on 382/384 trials).

Results

As predicted, when objects were visible, 11-month-olds in the current experiment showed robust novelty preferences, like 7-month-olds in Shinskey and Munakata (2005; Figure 2a). When objects were hidden, however, 11-month-olds maintained their novelty preference, in contrast to 7-month-olds who reversed to a familiarity preference (Figure 2b). Specifically, when objects were visible, 7- and 11-month-olds showed the same distribution of novelty vs. familiarity preferences, Mann-Whitney U, Z = -.71, $p > .45$. In both age groups, 20 infants reached more for novel than familiar objects, whereas none reached more for familiar than novel objects, and four reached equally, Wilcoxon Z = -3.95, $p < .001$. In contrast, when objects were hidden, 7- and 11-month-olds showed contrasting distributions of novelty vs. familiarity preferences, Mann-Whitney U, Z = -3.24, $p < .01$. Among 7-month-olds, only three infants reached more for novel than familiar objects, whereas 13 reached more for familiar than novel objects, and eight reached equally, Wilcoxon Z = -2.64, $p < .01$. Of these last eight infants, seven failed to reach at all, rather than reaching indiscriminately. Among 11-month-olds, eight infants reached more for novel than familiar objects, whereas only three reached more for familiar than novel objects, and 13 reached equally, Wilcoxon Z = -2.23, $p < .05$. Of these last 13 infants, nine failed to reach at all, rather than reaching indiscriminately.

Infants showed the same pattern across parametric analyses, with a marginal three-way interaction of age (7 or 11 months), visibility (visible or hidden), and familiarity (novel or familiar), $F(1, 46) = 2.84$, $p < .10$, $\eta_p^2 = .06$. This interaction reflects the fact that 7- and 11-month-olds showed the same novelty preference when objects were visible, but different preferences when objects were hidden. Specifically, when objects were visible, infants reached more for novel objects ($M = 92\%$ of trials, $SE = 3\%$) than familiar objects ($M = 44\%$, $SE = 4\%$), $t(47) = 11.82$, $p < .0001$, $d = 3.45$, and familiarity did not interact with age, $F(1, 46) = .40$, $p > .50$. In contrast, when objects were hidden, familiarity interacted with age, $F(1, 46) = 12.30$, $p < .01$, $\eta_p^2 = .21$. Seven-month-olds reached more for *familiar* objects ($M = 32\%$, $SE = 7\%$) than novel objects ($M = 20\%$, $SE = 5\%$), $t(23) = -2.97$, $p < .01$, $d = 1.24$, whereas 11-month-olds reached more for *novel* objects ($M = 31\%$, $SE = 7\%$) than familiar objects ($M = 17\%$, $SE = 5\%$), $t(23) = 2.20$, $p < .05$, $d = .92$.[1]

Changes across test trials were also consistent with the idea that object representations strengthened with experience, such that across the course of the experiment, 7- and 11-month-olds showed increasing novelty preferences with visible objects, and 7- but not 11-month-olds showed increasing exploration of the familiar object when it was hidden. Specifically, when objects were visible, infants' reaching for familiar objects *decreased* from trial 1 ($M = 58\%$, $SE = 7\%$) to trial 4 ($M = 31\%$, $SE = 7\%$), Wilcoxon $Z = -2.60$, $p < .01$, while their reaching for novel objects *increased* marginally from trial 1 ($M = 83\%$ of trials, $SE = 5\%$) to trial 4 ($M = 96\%$, $SE = 3\%$), Wilcoxon $Z = -1.90$, $p < .06$, and familiarity did not interact with age, Mann-Whitney U, $Z = -.14$, $p > .80$ (Figure 3). In contrast, when objects were hidden, familiarity interacted with age, Mann-Whitney U, $Z = -1.96$, $p = .05$. Specifically, 7-month-olds' reaching for familiar objects more than doubled from trial 1 ($M = 21\%$, $SE = 8\%$) to trial 4 ($M = 46\%$, $SE = 10\%$), Wilcoxon $Z = -2.12$, $p < .05$ (Figure 3a), whereas 11-month-olds' reaching for familiar objects did not change from trial 1 ($M = 17\%$, $SE = 8\%$) to trial 4 ($M = 13\%$, $SE = 7\%$), Wilcoxon $Z = -.45$, $p > .60$ (Figure 3b). Neither age group's reaching for novel hidden objects changed over trials.[2]

Discussion

This discovery of a developmental transition from familiarity to novelty preferences with hidden objects parallels the transition observed months earlier with visible objects (e.g. Bahrick *et al*., 1997; Rose *et al*., 1982). Each transition provides a distinct window onto developments in the strength of object representations and associated cognitive processes, suggesting different processes for visible versus hidden objects. With visible objects, the transition from familiarity to novelty preferences may reflect improvements in speed of processing that allow infants to form strong representations of familiar objects more rapidly (e.g. Rose *et al*., 2002; Rose, Feldman, Jankowski & Van Rossem, 2005). With hidden objects, the transition from familiarity to novelty preferences may reflect improvements in the ability to actively maintain information in the absence of environmental support (Kaufman, Csibra & Johnson, 2005; Munakata *et al*., 1997; Spelke & von Hofsten, 2001). With such improvements, representations and preferences with hidden objects come to resemble those with visible objects, such that representations of both familiar and novel hidden objects are sufficiently strong to support

[1] These proportional data were corrected with arcsine transformation to satisfy the assumption of homogeneity. Analysis of variance also yielded main effects of visibility, $F(1, 46) = 78.70$, $p < .0001$, $\eta_p^2 = .63$, and familiarity, $F(1, 46) = 82.87$, $p < .0001$, $\eta_p^2 = .64$, and interactions between visibility and familiarity, $F(1, 46) = 91.14$, $p < .0001$, $\eta_p^2 = .67$, and between age and familiarity, $F(1, 46) = 6.58$, $p < .05$, $\eta_p^2 = .12$. These effects and interactions are qualified by the interaction demonstrating that infants reverse their preferences over age when objects are hidden and not when objects are visible. Subsequent analyses indicate distinct interactions in each age group of visibility and familiarity. Whereas 7-month-olds reverse their novelty preference between visible and hidden conditions, $F(1, 23) = 40.08$, $p < .001$, $\eta_p^2 = .69$, 11-month-olds maintain their novelty preference but to a lesser degree with hidden than visible objects, $F(1, 29) = 51.33$, $p < .001$, $\eta_p^2 = .64$. Among 11-month-olds, this interaction may reflect that their representations are less precise for hidden objects than for visible objects.

[2] These results are presented using non-parametric analyses because the trial data consisted of binary measures (0 = no reach, 1 = reach).

manual search, and weaker representations of novel objects support greater exploration of them. This increasing ability to represent hidden objects like visible objects may contribute to a more abstract principle of object permanence, like that suggested by Piaget (1954) for infants older than 8 to 9 months.

Although the transition from familiarity to novelty preferences with hidden objects reveals a behavioral discontinuity with development, which may appear inconsistent with core knowledge perspectives (Spelke & Kinzler, 2007), older infants (and even adults) might nonetheless revert to familiarity preferences under conditions that interfere more with their representations of hidden objects. For example, delays might be imposed after objects are hidden, or a visible occluder might provide more interference than the darkness manipulation used in the present work (Munakata *et al*., 1997; Shinskey, 2008; Shinskey & Munakata, 2003). Familiarity preferences like those observed in 7-month-olds might emerge under these circumstances, because the weakening of object representations should lead the relatively stronger representations of familiar objects to be more likely to support search. In the same way, under demanding conditions adults can revert to patterns of behavior suggesting continuity of processing mechanisms across development, consistent with core knowledge perspectives, in object processing (Mitroff, Scholl & Wynn, 2004), spatial processing (Hermer-Vazquez, Spelke & Katsnelson, 1999), and cognitive flexibility (Diamond & Kirkham, 2005). For example, in visual paired comparison tasks, adults show novelty preferences after a 3-m delay but revert to familiarity preferences after a 12-month delay (Richmond, Colombo & Hayne, 2007).

The developmental transition from familiarity to novelty preferences with hidden objects may thus reflect both change and continuity in the underlying representations and processes: change in the strengthening of representations, such that both novel and familiar objects become represented sufficiently strongly to support search and to possibly support a more abstract understanding of object permanence, and continuity in familiar objects being represented more robustly than novel objects, leading to novelty preferences in the current study that might revert to familiarity preferences under more demanding conditions. Thus, although novelty seeking can be adaptive and predictive of long-term cognitive outcomes, familiarity preferences and associated transitions can reveal adaptive processes in the development of object representations.

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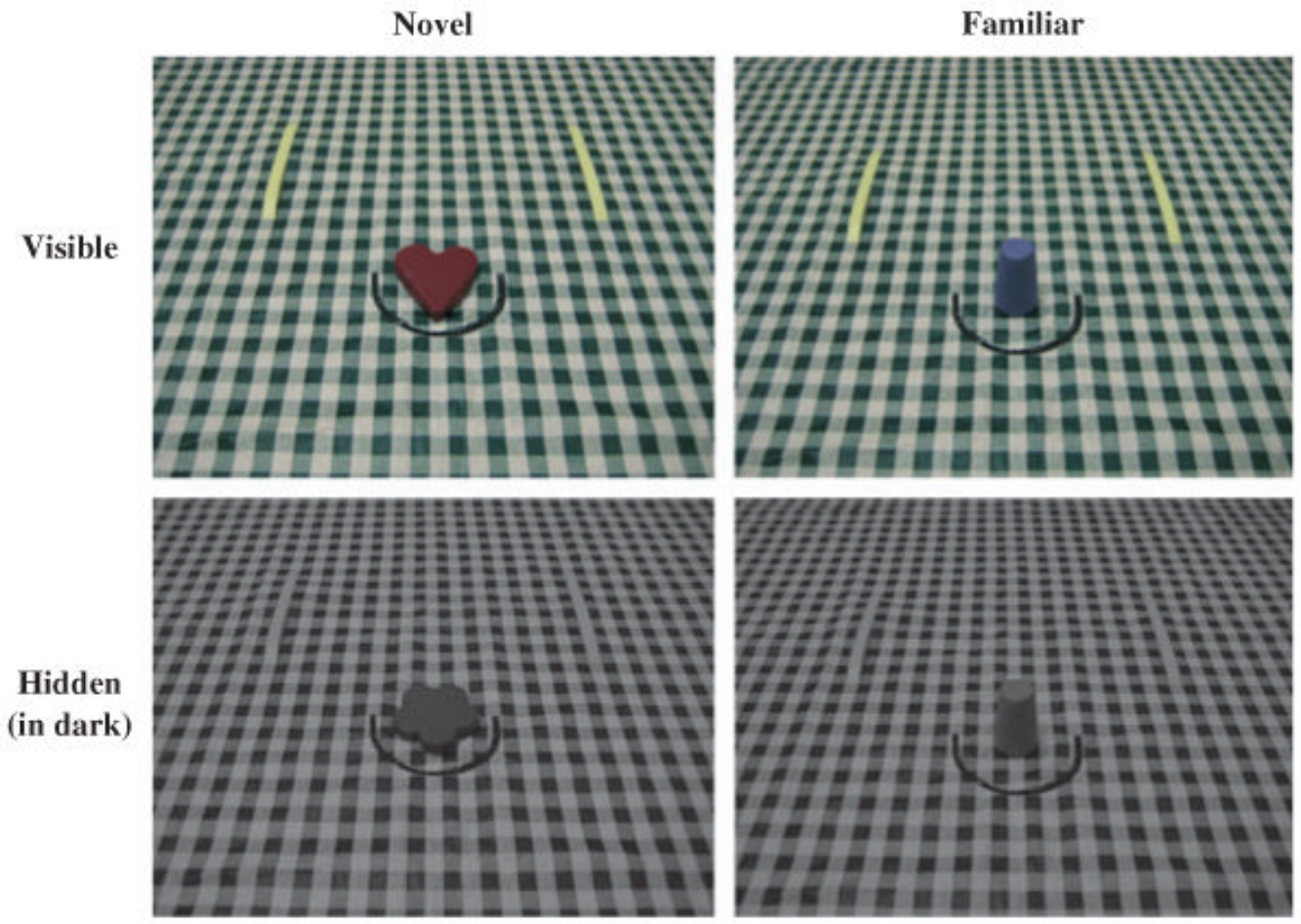

Figure 1.

The four types of test trials with novel and familiar objects visible in the light or hidden in the dark. Trials in the dark are depicted using shaed images but were completely dark from the infant's perspective, with the exception of the two glow-in-the-dark strips of tape flanking the search space. The semi-circular search space depicted on the table was not visible to infants but was instead marked on the observer's video monitor for coding purposes. To equate for attractiveness, the object designated 'familiar' was counterbalanced across participants. The familiar object was the same across all familiar trials, whereas each novel trial introduced a unique novel object.

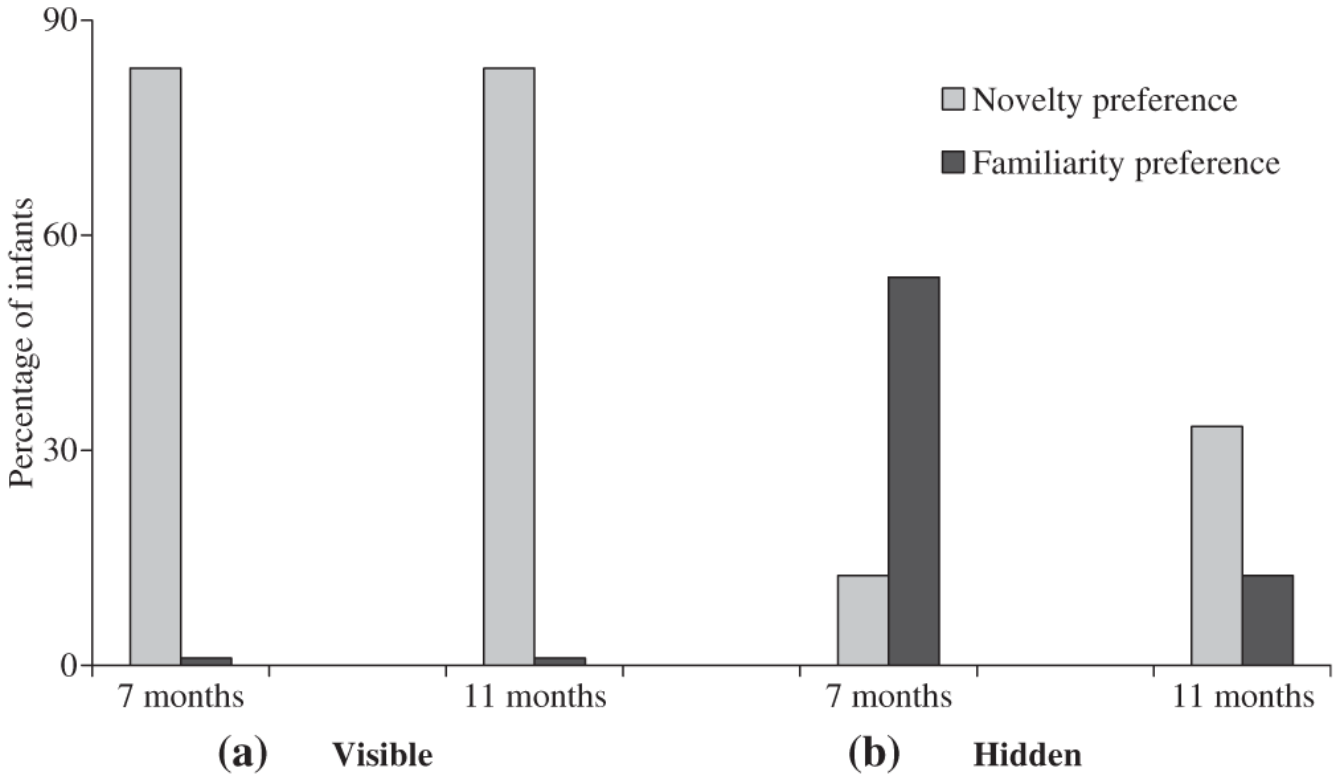

Figure 2.
Seven- and 11-month-olds showed the same novelty preference when objects were visible, but contrasting preferences when objects were hidden. Data from 7-month-olds are from Shinskey and Munakata (2005).

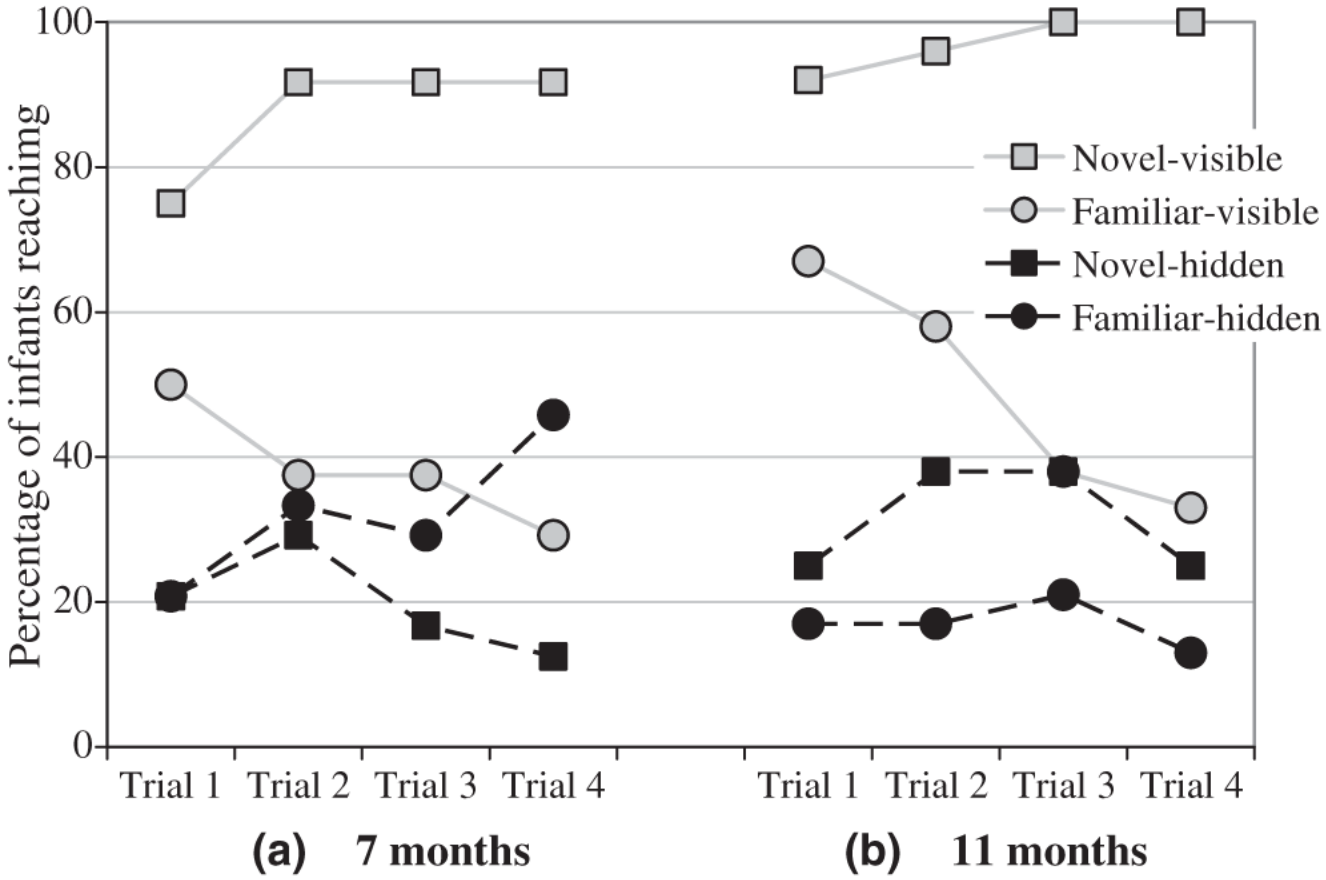

Figure 3.
Changes across test trials reflect less exploration of the familiar object at both 7 and 11 months when it was visible, but greater exploration of the familiar object at 7 and not 11 months when it was hidden. Data from 7-month-olds are from Shinskey and Munakata (2005).