To Grasp or Not to Grasp: Infants’ Actions Toward Objects and Pictures

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We conducted two experiments to address questions over whether 9-month-old infants believe that objects depicted in realistic photographs can be picked up. In Experiment 1, we presented 9-month-old infants with realistic color photographs of objects, colored outlines of objects, abstract colored “blobs,” and blank pages. Infants most commonly rubbed or patted depictions of all types. They also showed significantly more grasps toward the realistic photographs than toward the colored outlines, blobs, and blank pages, but only 24% of infants directed grasping exclusively at the photographs. In Experiment 2, we further explored infants’ actions toward objects and pictures while controlling for tactile information. We presented 9-month-old infants with objects and pictures of objects under a glass cover in a false-bottom table. Although there were no significant differences between the proportion of rubs and pats infants directed toward the objects versus the photographs, infants exhibited significantly more grasping toward the objects than the photographs. Together, these findings show that 9-month-old infants largely direct appropriate actions toward realistic photographs and real objects, indicating that they perceive different affordances for pictures and objects.
Infants frequently encounter two-dimensional representations (e.g., pictures and photographs) of objects in their day-to-day life. For example, adults often read picture books to infants, many of which contain highly realistic pictures and photographs of animals, objects, and people. How infants understand such depictions is an important developmental question that has received considerable attention in the field of infant perception (e.g., DeLoache, Pierroutsakos, & Uttal, 2003; DeLoache, Pierroutsakos, Uttal, Rosengren, & Gottlieb, 1998; DeLoache, Strauss, & Maynard, 1979; Yonas, Granrud, Chov, & Alexander, 2005). One question in particular is, Do infants recognize that highly realistic pictures and photographs are different from the real objects they depict? Or do they try to interact with pictures and photographs in the same way as three-dimensional objects? Some researchers have claimed that infants mistake the properties of two-dimensional depictions and try to interact with them as if they were three-dimensional (e.g., attempting to pick them up; DeLoache et al., 1979, 1998, 2003). Other researchers have claimed that infants know the difference between two- and three-dimensional objects, and direct appropriate exploratory behaviors toward objects and pictures (e.g., Yonas et al., 2005). This investigation further examines the types of manual actions infants direct toward two-dimensional depictions of varying realism and toward three-dimensional replicas of those depictions in order to gain a better understanding of how infants perceive pictures and objects.

Much of the conversation concerning how infants perceive two- and three-dimensional objects has been motivated by work conducted by DeLoache and her colleagues (DeLoache et al., 1979, 1998, 2003; Pierroutsakos & DeLoache, 2003). Their studies show that when 9-month-old infants are presented with realistic color photographs of objects in a picture book, they manually explore the photographs by feeling, rubbing, patting, and grasping at the pages. In contrast, older infants tend to point at the photographs more and exhibit a decline in the type and amplitude of manual behaviors typical of younger infants (DeLoache et al., 1998). Based on this evidence, DeLoache et al. (1998, 2003) argue that 9-month-old infants have not yet achieved "pictorial competence," or an understanding that a picture is both an object in and of itself and also a representation of something else. Until infants understand the dual nature of representations, they will attempt to interact with depictions as if they were the objects they represent. From this perspective, pictorial competence represents a high-level, qualitative change in how infants understand two-dimensional representations of objects.

Further work by Pierroutsakos and DeLoache (2003) showed that the more realistic the depictions, the more infants manually explore them. They presented 9-month-old infants with color photographs, black-and-white photographs, colored line drawings, and black-and-white line drawings in a
picture book. Infants directed the most actions toward the color photographs and the least toward the line drawings. Pierroutsakos and DeLoache conclude that the manual exploration infants exhibit toward two-dimensional pictures is driven by the picture’s similarity to its three-dimensional counterpart. The more realistic the depiction, the more infants will manually explore and grasp at the picture and respond to it as if it were a three-dimensional object.

Other work on infant picture perception has raised questions about whether infants perceive photographs as graspable. A study by Yonas et al. (2005) compared 9-month-old infants’ manual behaviors when presented with an object, a photograph of that object, or a two-dimensional nonpictorial display. They examined infants’ hand height and angle when reaching for these two-and three-dimensional objects as well as the type of manual behaviors exhibited toward them. Mean hand height and angle in the object condition differed significantly from mean hand height and angle in the two-dimensional conditions. Infants reached toward the three-dimensional object with a hand height and angle that would facilitate grasping the object. Infants reached toward the two-dimensional depictions with a hand height and angle that would facilitate rubbing or scratching a flat surface. Yonas et al. found no difference in the hand height or angle used toward the photographs and the nonpictorial displays. Similarly, when presented with a photograph of an object and a photograph of textured carpet, infants did not exhibit different manual behaviors. The authors conclude that 9-month-old infants do not treat photographs of objects as if they were graspable, but rather, they explore them as they would any other two-dimensional surface.

A recent study by Shuwairi, Tran, DeLoache, and Johnson (2010) examined 9-month-old infants’ behaviors directed toward depictions of geometrically possible and impossible objects. They found that infants directed a significantly greater number of actions toward depictions of impossible objects. Infants not only exhibited more manual behaviors toward the impossible object depictions but displayed more social referencing, vocalizations, and mouthing with these depictions as well. However, although Shuwairi et al. classified manual actions into categories of touching, grasping, rubbing, scratching, and patting, they did not find that infants were directing different types of actions toward the possible and impossible object displays. If 9-month-old infants really believe that they can grasp these depicted objects, one might expect that infants would exhibit more behaviors toward geometrically possible displays. However, in this case, the authors suggest that infants may be manually exploring depictions that are more visually interesting or novel.

Work by DeLoache et al. (1979, 1998, 2003) and Yonas et al. (2005) indicate that there is still no agreement as to how infants understand
two-dimensional depictions of objects. There are remaining concerns on both sides of the argument, however, which may make any conclusions on this topic premature. One concern with the Pierroutsakos and DeLoache (2003) study was that although they found a linear relationship between the level of realism in the depictions and the amount of actions directed toward them, they did not find a significant difference in the actual number of behaviors directed toward the color photograph and the black-and-white photograph or colored line drawing. Furthermore, they found no significant differences between the black-and-white photograph, the colored line drawing, and the black-and-white line drawing. The only significant difference was between actions directed toward colored photographs and black-and-white line drawings. This raises the question of whether infants actually grasp more at depictions that are more realistic. One way to test this hypothesis is to look at how infants explore two-dimensional depictions of nonobjects (such as an abstract colored “blob”) that contain the same edge and color information as a photograph of an object. If infants treat this nonobject depiction the same as a line drawing or photograph of an object, it would suggest that infants are not in fact scaling their actions to the realism of the depiction.

Another concern is that in the Pierroutsakos and DeLoache (2003) study, the type of depiction (i.e., color photograph, black-and-white photograph, and line drawing) was manipulated between participants rather than within participants. This type of design does not allow us to compare what the same infant does with different types of depictions. It is important to see the change in behavior from one type of depiction to another in order to control for an infant’s tendency to do one type of manual behavior. Seeing the same infant who pats and rubs a line drawing switch to grasping when presented with a color photograph would be much stronger evidence for DeLoache et al.’s (2003) hypothesis that infants are treating these photographs differently from other two-dimensional depictions. On the other hand, if an infant shows the same pattern of behavior across all types of depictions, it may indicate that she is merely using these behaviors to explore the surfaces in front of her.

A final concern with the work by DeLoache et al. (1998, 2003) is their coding scheme for classifying infants’ manual behaviors. Behaviors were grouped into one of two types: “grasping” and “other deliberate investigative behaviors.” Grasping was defined as a “change of hand shape or curling of the finger(s) after contacting the surface of the page... appeared to the coders to be an attempt to pick up the depicted object” (DeLoache et al., 1998, p. 206). The other investigative behaviors included things like feeling, hitting, and rubbing (DeLoache et al., 1998; Pierroutsakos & DeLoache, 2003). However, the coders did not discriminate between different types of
actions in the “other behaviors” group. It is important to know what types of actions infants are directing toward depictions in order to understand how they might be trying to interact with them. In particular, actions such as rubbing and patting are appropriate ways of exploring a flat surface, whereas an action such as grasping is not. If 9-month-old infants perceive different affordances for two-dimensional depictions of objects and the real objects, we would expect to see far more rubbing and patting than grasping of depictions of all levels of realism. Shuwairi et al. (2010) did not find differences in the patterns of actions (touching, grasping, rubbing, scratching, and patting) directed toward geometrically possible and impossible depictions. However, any differences between these actions may have been obscured by the novelty of the geometrically impossible objects. Here, we sought to further examine whether infants direct different types of manual actions toward depictions of objects varying in realism and toward real objects under glass.

The Yonas et al. (2005) study revealed that infants reached differently for two- and three-dimensional objects; however, they did not control for tactile information. Upon making contact, the tactile feedback infants received when they manually explored the object was different from the feedback they received from the photograph of the object. This feedback may have influenced their subsequent reaches toward the object or photograph. For example, once an infant makes contact with a three-dimensional object, she may know something about the properties of that object that she did not know from just looking at it. Further reaches toward the object may reflect this knowledge (i.e., she may be more likely to grasp at it). Another concern is that Yonas et al. used the same object (a Bert doll) for both the three-dimensional object and the subject of the two-dimensional photograph. As this was a within-subjects design, prior experience with either the three-dimensional doll or the photograph of the doll may have affected how the infants interacted with other versions of that doll in the study.

In this investigation, we further examined how infants interact with two-dimensional pictures and three-dimensional objects. The goal of the first experiment was to examine how 9-month-old infants interact with depictions using a more detailed and objective coding scheme, a within-participants design, and additional depiction types. In order for us to examine a gradation of two-dimensional representations, 9-month-old infants were presented with color photographs, color outline drawings, color blobs, and blank pages. Coders noted the presence or absence of four types of actions—grasps, pats, rubs, and scratches. If infants are directing grasps at colored outlines, blobs, and blank pages, then this type of action toward two-dimensional surfaces may not reflect a belief that objects in pictures can be grasped, but rather may reflect a type of exploratory behavior aimed at discovering the properties of surfaces. We also were interested in whether
infants utilized some manual behaviors more than others (e.g., rubbing and patting over grasping), and whether infants were more likely to grasp at highly realistic photographs than at the other depiction types.

The goal of the second experiment was to examine how infants interact with two-dimensional photographs of objects as compared to three-dimensional objects when tactile information is held constant. We presented 9-month-old infants with objects and photographs of these objects under plexiglass in a false-bottom table. The plexiglass cover allowed infants to see the photographs and objects but did not allow any discriminating tactile information between the two-dimensional photographs and three-dimensional objects. Based on previous research by Lockman and Adams (2001) investigating infants’ ability to obtain an object on the other side of a transparent barrier, we had reason to believe that infants would attempt to contact the photographs and objects through the plexiglass. Again, we coded the presence or absence of grasps, pats, rubs, and scratches. If infants perceive a two-dimensional photograph as if it were a three-dimensional object, they should show similar manual behaviors toward both the photographs and objects under the plexiglass. However, if infants exhibit different behaviors toward the photographs and objects, it would indicate that they have some understanding about the different ways they should be able to interact with these photographs and objects.

EXPERIMENT 1

Method

Participants

Forty-five 9-month-old infants (24 females) participated in Experiment 1. Only full-term infants were recruited for the study. An additional 10 infants participated, but were excluded from the analyses for the following reasons: too fussy to complete the task \((n = 1)\), sibling or parent interference in the task \((n = 2)\), and problems with the video-recording equipment \((n = 7)\). The mean age of participants in Experiment 1 was 9 months 15 days (range = 8 months 27 days to 10 months 1 day).\(^1\) Participants were recruited through a child research participant database maintained by the psychology department at two Midwestern universities. Parents received a letter describing the study, followed by a telephone call inviting them to participate. Participants were predominantly Caucasian and middle class.

\(^1\)One infant was not included in the mean age calculation owing to missing birth date information.
Materials

The objects depicted were presented in three formats: full-color photographs, colored outlines, and “blobs,” all printed in photograph quality onto glossy photograph paper on a laser color printer. “Blobs” were swirled images that preserved the color, contrast, and highlights of the original photograph, but not the contour, making them nonrepresentational. Colored outlines and blobs were created using Photoshop CS2 version 9.0.2 (Adobe, San Jose, CA). To create colored outlines, we used the “Glowing Edges” option under the Stylize Filter and then added an inverted layer to invert the colors, creating a white background. To create blobs, we used the “Twirl” option under the Distort Filter and twirled the photograph approximately 316°. Depictions were glued to a large foam board (32 in. × 13.5 in.). The foam board was placed on top of the table inside a low wooden frame (3/8 in. high) to keep the foam board from sliding around and to prevent infants from grabbing for the edges of the board or trying to pick it up.

Twenty participants were presented depictions and blanks against a white background, and 25 participants were presented with depictions and blanks against a black background. These different colored backgrounds were used in order to see whether infants would be more attracted to an area of high contrast (white paper on black background) than to the target depiction. However, we found no difference between infants’ manual behaviors in the black background versus the white background condition, so these two groups were combined in our analyses.

Infants saw four examples of each type of depiction (photographs, colored outlines, and blobs), as well as four blanks. Depictions were 4.5 in. × 3 in. on average (4.3 in. × 2.9 in. for photographs and colored outlines; 4.6 in. × 3.1 in. for blobs). Photographs of objects were taken from overhead at a slightly oblique angle, allowing them to be maximally informative as to the object’s solid shape (see Figure 1). The 12 objects included a tube of

![Figure 1](image1.png)  
**Figure 1** Example of three types of depictions used in Experiment 1: photographs, colored outlines, and blobs.
toothpaste, toy keys, a toy stuffed cat, a toy stuffed monkey, a toy horn, a toy caterpillar, a toy camera, a toy phone, a bear rattle, a flower rattle, a rattle with four roller balls, and a colorful abstract rattle.

**Procedure**

Thirty-four of the 45 infants in Experiment 1 sat on their parent’s lap in front of a small table. The experimenter sat directly across the table from the child and parent. Parents were instructed to hold their children loosely around their waist and not to interfere with their arms or to touch the table themselves. The parents of 11 infants chose to have their infant sit in a booster seat at the table instead of on their lap. Although parents were not blindfolded and were allowed to talk during the session, they were not informed of the purpose of the study until after the experimental session was complete. Any infant whose parent touched the table during the experimental session was dropped from the analysis. The session started with a brief warm-up period during which the experimenter played with the infants using a stuffed toy or puppet. The warm-up served two purposes: we wanted the infants to get used to the experimenter and to engage in the task, and we also wanted infants to reach forward in order to make sure they were close enough to reach the depictions on the table. The toys used during the warm-up period were never the same as any of the toys depicted in the photographs, colored outlines, or blobs.

Each of the 12 depictions and four blanks were placed one at a time on the table in front of the infant. Infants were allowed to explore the depictions freely until they lost interest. If an infant did not look at the depiction, the experimenter would direct their attention to it by tapping on the table (but not the depiction). Experimenters were careful to never actually tap on the foam board that displayed the depiction. Once an infant lost interest in the depiction, the experimenter would take it away and present the next depiction. We allowed infants unlimited time in order to provide them with every opportunity to manually interact with the depictions. Very few actions occurred after infants lost interest in a depiction, so the trial was ended at that point. Presentations of depictions lasted an average of 17.2 sec for blanks, 24.8 sec for blobs, 23.3 sec for colored outlines, and 29.2 sec for photographs. If an infant became fussy during the experiment, he or she was allowed to take a break and then try to resume. None of the infants in this study took more than one break during the testing session.

For each infant, objects were randomly paired with depiction types with the constraint that infants never saw the same object more than once and they saw four of each depiction type. The depictions and blanks were then randomly grouped into four blocks of four trials with the restriction that
participants saw each type of depiction (photograph, colored outline, and blob) and a blank in each block of trials. The order of depictions within each block was random.

Sessions were video-taped from four different angles (directly above, from the left, from the right, and head on) for 28 infants in Experiment 1 and from two different angles (directly above and head on) for 17 infants in Experiment 1 and for all infants in Experiment 2. (We used fewer angles for these latter infants because all four angles were deemed unnecessary for accurate coding of manual actions.) These images were then fed through a mixer, allowing them to be viewed simultaneously on one screen or synced together using iMovie Mac video program (Apple, Cupertino, CA). At the end of the session, infants were given a toy for participating in the study.

**Coding**

Infants’ manual behaviors toward the photographs, blobs, colored outlines, and blank surfaces were coded from the videotapes by the third author. Only manual behaviors that came into contact with the depiction were coded (except for blank surfaces in which there was no depiction). Coders recorded presence or absence of pats, rubs, scratches, and grasps for each of the 16 test trials. Pats were hand movements that came in contact briefly with the depiction, either lightly touching or slapping the surface of the depiction. Rubs were hand movements that swept across the depiction. Scratches were hand movements in which one of the infant’s fingers (usually the index finger or thumb) flexed and extended while in contact with the depiction. Grasps were hand movements in which the infant’s four fingers (with or without the thumb) flexed closed into a fist while in contact with the image (Butterworth, Verweij, & Hopkins, 1997). Each trial began when the infant first looked at the depiction and ended when the depiction was removed. Intercoder reliability ($N = 9$ infants) based on exact percent agreement (i.e., whether each action was present or absent on each trial) was 93.75%.

Proportion scores were computed by taking the number of trials of each depiction type in which a given action occurred divided by the number of trials an infant completed for each depiction type. Like Yonas et al. (2005), we chose to use the proportion of trials in which each action was displayed in order to more objectively and conservatively evaluate infants’ reaching behavior toward depictions. The use of proportions allows even occasional

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2We originally coded single-finger rubs, pats, or grasps (pincher grasp) separately from whole-hand gestures. However, these behaviors were very infrequent and so we decided to combine single-finger and whole-hand gestures within each category.
behaviors to be represented in the data (like grasps) and is less subjective than counting the number of occurrences for each individual behavior. For example, although DeLoache and colleagues (e.g., Pierroutsakos & DeLoache, 2003) have reported the number of behaviors directed toward depictions in their work, the coding criteria for determining a new behavior included things like switching hands or looking away. With these coding criteria, alternating hand pats would be counted as separate behaviors while a 20-sec rub during which the infant never lifted his or her hand off of the depiction would be counted as only one behavior.

Results and discussion

Figure 2 shows the mean proportion of trials in which infants directed grasps, pats, rubs, and scratches toward the photographs, blobs, colored outlines, and blanks. Overall, the most frequent action directed toward the depictions was rubbing, followed by patting. Grasping and scratching were relatively infrequent. We examined whether 9-month-old infants performed different manual behaviors toward different types of depictions using two types of analysis. We first entered the proportion of grasps, pats, rubs, and scratches into an Action (4) × Depiction (4) analysis of variance (ANOVA). There were significant effects of action, $F(3, 132) = 126.42, p < .0001$, $\eta^2_p = .74$, and depiction, $F(3, 132) = 19.76, p < .0001$, $\eta^2_p = .31$. Protected least significant difference (PLSD) follow-up tests of the action effect showed that all actions differed significantly from each other except for grasps and scratches. The mean proportion of trials in which infants exhibit-

![Figure 2](image)

Figure 2  Mean proportion of grasps, scratches, rubs, and pats to photographs, colored outlines, blobs, and blanks in Experiment 1.
ited rubs, pats, grasps, and scratches were .68 (SD = .20), .34 (SD = .24), .11 (SD = .14), and .05 (SD = .09), respectively.

There was also a significant Action × Depiction interaction, $F(9, 396) = 3.81, p < .0001, \eta^2_p = .08$. We conducted simple effects tests to determine whether there was a significant effect of depiction for each type of action. The effect of depiction was significant for grasps, $F(3, 132) = 12.21, p < .0001, \eta^2_p = .22$, scratches, $F(3, 132) = 11.74, p < .0001, \eta^2_p = .21$, and rubs, $F(3, 132) = 10.64, p < .0001, \eta^2_p = .19$, but not for pats, $F(3, 32) = 1.12, ns$.

As shown in Figure 1, follow-up tests using Fisher’s PLSD showed that infants grasped and scratched significantly more toward photographs, colored outlines, and blobs than toward blanks, and more toward photographs than colored outlines or blobs. However, the proportion of grasps and scratches did not differ significantly between colored outlines and blobs. Similarly, infants exhibited significantly more rubs toward photographs than toward colored outlines, blobs, or blanks. Infants also directed significantly more rubs toward blobs and colored outlines than toward blanks. Infants exhibited a high proportion of pats overall, and there were no significant differences in pats directed toward photographs, colored outlines, blobs, and blanks.

We also examined whether the pattern of actions across individual infants differed. We found that 24% of infants grasped only toward photographs, 24% of infants grasped toward at least one photograph and one other type of depiction, 4% of infants grasped at all four types of depictions, 18% of infants grasped only at nonphotographs, and 29% of infants never grasped. Of the infants who grasped exclusively at photographs, all but one grasped only at one of the four available photographs. The remaining infant grasped at two photographs. Together, these results show that infants exhibited far more rubbing and patting than grasping and scratching toward the depictions. In addition, although infants exhibited more grasping to the photographs than to the other types of depictions, they did not scale their level of grasping to the level of realism of the depictions. Instead, they showed identical amounts of grasping to the colored outlines and the blobs. Moreover, a minority of infants exhibited discriminative grasping (i.e., only to photographs) relative to those who exhibited nondiscriminative grasping (i.e., photographs and other types of depictions), and no grasping toward depictions at all. Thus, although the photographs elicited more grasping than the other types of depictions, grasping was by no means directed exclusively at the photographs.

In Experiment 2, we examined the extent to which realistic photographs elicited grasping relative to real objects when tactile information was controlled (i.e., the photographs and objects were under glass). A plexiglass cover over both the photographs and the objects allowed us hold tactile
information constant in order to directly compare the manual actions produced by 9-month-old infants in response to the photographs and objects. The plexiglass cover also stopped infants from using tactile information about the three-dimensional objects to color their subsequent reaches toward the objects.

EXPERIMENT 2

Method

Participants

Twenty-one 9-month-old infants (nine females) participated. No infants from Experiment 1 participated in Experiment 2. Only full-term infants were recruited for the study. The mean age was 9 months 14 days (range = 8 months 18 days to 10 months 3 days). An additional two infants participated, but were excluded from the analyses for equipment problems (n = 1) and parental interference (n = 1). Infants were recruited in the same manner as in Experiment 1.

Materials

The materials consisted of full-color photographs of objects or the actual three-dimensional objects. Both the objects and the photographs of the objects were presented under a plexiglass surface in a false-bottom table. The plexiglass lid of the table was attached to the front of the table with a hinge, allowing the experimenter to lift up the lid in order to change the photograph or object. The false bottom of the table consisted of two 8.5 in. × 8.5 in. square wells. The background of the wells was painted white and the depth could be adjusted so that objects and photographs sat just beneath the plexiglass surface.

The 10 objects used were toy keys, a toy stuffed monkey, a toy horn, a toy caterpillar, a toy camera, a toy phone, a bear rattle, a flower rattle, a rattle with four roller balls, and a colorful abstract rattle (note that these were 10 of the 12 objects used in Experiment 1). The photographs had an average length of 4 in. and an average width of 2.9 in. The objects had an average length of 5.1 in., an average width of 3.2 in., and an average height of 2.2 in. Infants saw five photographs and five objects in a random order. Again, infants saw either the photograph of the object or the actual object, but never both forms of the same object because we did not want infants’ to be influenced by previous experience with a different version of the same object. Whether infants saw the actual object or its photograph was randomly determined. Objects and photographs were presented on either the left or
the right side of the table (randomly ordered with equal number of trials on each side), opposite a blank white piece of foam board.

**Procedure**

Infants sat on their parent’s lap in front of the table. Parents were instructed to hold their infants loosely around their waist and to not interfere with their arms or to touch the table themselves. The session started with a brief warm-up period during which the experimenter played with the infants using a stuffed toy. The warm-up session again served to engage the infant and make sure he or she could reach the table. During the warm-up session and between trials, a piece of colored tag board covered the plexiglass table so that the infants were not able to see the two wells underneath. Once a photograph or object was in place, the experimenter lowered the plexiglass cover and removed the colored tag board from the table. Infants were allowed to explore freely until they lost interest. If an infant did not look at the object or photograph, the experimenter would direct their attention to it by tapping on the table (but not directly over the wells). When the infant lost interest in the trial, the experimenter would cover the table with the tag board and then lift the plexiglass lid to switch to the next photograph or object.

If an infant became fussy during the session, he or she would be allowed to take a break and then try to resume the session. Sessions were video-taped from two different angles—overhead and head on. These two views were then combined using a computer program so that they could be viewed simultaneously side by side. At the end of the session, infants were given a toy to thank them for their participation.

**Coding**

Infants’ manual behaviors toward the photographs and objects were coded from the videotapes. Only manual behaviors that came in contact with the well area around the photograph or object were counted. Again, four behaviors were coded, pats, rubs, scratches, and grasps, using the same coding criteria as used in Experiment 1. Although the trial lengths in Experiment 2 were again infant-controlled, only the first 30 sec were coded. As in Experiment 1, each trial began when the infant first looked at the well area. Coders recorded presence or absence of pats, rubs, scratches, and grasps for each of the 10 trials. In addition, coders recorded the presence or absence of each type of behavior in the first 10 sec of each trial. Proportion scores were calculated by taking the number of trials in which a behavior occurred divided by the number of completed trials of each type (photographs and...
objects). Intercoder reliability ($N = 4$ infants) based on exact percent agreement was 92.5%.

Results and discussion

Figure 3 shows the mean proportion of different actions directed toward the photographs and objects. Once again, grasps were the least frequent behavior, followed closely by scratches. Rubs were by far the most frequent behavior with pats falling between rubs and scratches and grasps. To address whether 9-month-old infants performed different manual behaviors toward the objects and photographs, we entered the proportion of grasps, pats, rubs, and scratches into an Action ($4$) \times Display ($2$) repeated measures ANOVA. The analysis yielded a significant effect of action, $F(3, 60) = 64.51, p < .0001$, $\eta_p^2 = .76$, and display, $F(1, 20) = 7.03, p < .05$, $\eta_p^2 = .26$. PLSD follow-up tests of the action effect showed that all actions differed significantly from each other except for grasps and scratches. The mean proportion of trials in which infants exhibited rubs, pats, grasps, and scratches were $0.93$ ($SD = .11$), $0.48$ ($SD = .25$), $0.24$ ($SD = .24$), and $0.15$ ($SD = .16$), respectively.

There was also a significant Action \times Display interaction, $F(3, 60) = 3.39, p < .05$, $\eta_p^2 = .14$. Simple effects tests showed that infants grasped significantly more toward objects than photographs, $F(1, 20) = 13.77, p < .01$, $\eta_p^2 = .41$. Likewise, there was a trend for infants to scratch more toward objects than toward photographs, $F(1, 20) = 4.03, p < .06$, $\eta_p^2 = .17$. There were no significant differences in pats or rubs directed toward objects and photographs.
In addition to the overall ANOVA, we also analyzed infants’ actions by looking at what actions were present during the first 10 sec of each trial. Arguably, the first 10 sec is the most interesting as it reveals infants’ first impressions of the affordances of the photograph or object. We believe that these initial interactions reveal the infants’ attempts to interact with the three-dimensional objects before they get the contradictory tactile feedback. As shown in Figure 4, there was a significant difference between the proportion of grasps as well as rubs directed toward objects and photographs in the first 10 sec of trials. Pats and scratches were not preferentially directed toward objects or photographs in the first 10 sec.

As in Experiment 1, we also examined individual patterns of grasping. We found that no infants grasped only toward photographs, but 43% of infants grasped only toward objects. Thirty-eight percent of infants grasped at both photographs and objects, and 19% of infants never grasped.

Together, these results show that when tactile information differences between photographs and objects were controlled, infants showed significantly more grasping toward objects than photographs. This difference was also seen in the first 10 sec of a trial, suggesting that the infants very quickly noticed the difference between the photographs and objects. The results of Experiment 2 are in alignment with Yonas et al.’s (2005) study, which found differences in the way infants reached toward objects and photographs. However, by using different photographs and objects for each trial and by controlling tactile feedback between the two, the current study ensures that this difference in behavior was not driven by any direct feedback with the photographs or objects within the testing session.

Figure 4 Mean proportion of rubs, pats, scratches, and grasps to photographs and objects during the first 10 sec of trials in Experiment 2.
GENERAL DISCUSSION

These studies show that 9-month-old infants directed a variety of manual actions toward two-dimensional depictions of objects and three-dimensional objects under glass. The most common action by far was rubbing the hands across the surfaces, followed by patting the surfaces. The least common actions were grasping and scratching at the surfaces. Even when presented with highly realistic photographs in Experiment 1, infants were far more likely to use rubbing or patting actions than grasping actions. In both experiments, the associated effect sizes were large, indicating robust differences in the actions infants used to explore the surfaces. Furthermore, we found that only 24% of infants in Experiment 1 grasped exclusively toward photographs, and many infants showed no grasping or grasped toward depictions of varying realism (including blank pages). Although we did find that infants exhibited more grasping to photographs than to other depictions, we did not find that infants scaled their grasping to the representational realism of the other depictions. Infants grasped equally to the colored outlines of the objects and to the nonrepresentational swirls of the objects. We also found that infants behaved differently toward photographs and objects under glass, exhibiting significantly more grasping toward the objects than the photographs even though neither could be grasped. This difference was evident even in the first 10 sec of a trial.

What do these results tell us about infants’ manual actions toward depictions? First, our detailed coding scheme revealed that infants largely behaved appropriately toward the various two-dimensional depictions that they encountered. The vast majority of infants’ actions consisted of rubbing or patting the depictions, indicating that infants geared their actions toward the two-dimensional properties of the depictions. We argue that patting and rubbing are more appropriate ways of interacting with a two-dimensional (flat) surface. These actions give tactile information about a two-dimensional surface and do not indicate an expectation for three-dimensional qualities (such as the ability to grasp an object). Second, the analyses of both group and individual patterns of behavior indicate that grasping was not representative of infants’ actions toward photographs. At the group level, infants exhibited grasping toward photographs on about 20% of trials. At the individual level, a small minority of infants (24%) grasped only toward photographs. The majority of infants showed no grasping or grasped toward depictions of varying realism, including blank pages. And third, infants recognized differences in the graspability of real objects and realistically depicted objects. They showed a clear preference for grasping at objects over photographs even when a glass surface prevented them from making contact with either. In fact, a comparison of effect sizes shows that
the effect of display on grasping was nearly twice as large in Experiment 2 than in Experiment 1. Together, these findings indicate that even at 9 months of age, infants recognize that a depicted object is not the same thing as a real object.

Our results add to previous work by Yonas et al. (2005) showing that 9-month-old infants exhibit different kinds of manual behaviors toward real and depicted objects. They found that infants reached at hand heights and angles that would facilitate grasping the real objects and would facilitate rubbing the depicted objects. In our second experiment, we took the complementary approach of equating the surface characteristics of real and depicted objects to examine whether infants were more likely to direct grasping actions at the real objects than at the realistic photographs. Even though infants were thwarted in their attempt to make contact with either the objects or photographs, they were much more likely to grasp at the objects than at the photographs. These differences in how infants act toward real objects and realistic photographs are also consistent with other evidence showing that infants recognize both the similarities and differences between real and depicted objects (DeLoache et al., 1979; Dirks & Gibson, 1977; Jowkar-Baniani & Schmuckler, 2011). For example, even 5-month-old infants will look longer at a real doll next to a picture of the same doll (DeLoache et al., 1979), but when 9-month-old infants are habituated with a three-dimensional doll, they do not show a novelty preference to a line drawing of that same doll (Jowkar-Baniani & Schmuckler, 2011).

Together, these findings cast doubt on the idea that infants’ understanding of pictures undergoes a qualitative shift near the end of the first year. Rather, 9-month-old infants largely interact appropriately with realistic photographs and real objects, indicating that they perceive different affordances for pictures and objects. Such a view fits with the fact that most infants have had a vast amount of experience with objects and pictures by 9 months of age. This prior experience with exploring pictures and objects provides infants with many opportunities to learn about the affordances of pictures and objects. Infants learn that depicted objects can be rubbed and patted, but not picked up. As seen in the present investigation, infants bring this experience with them into the laboratory and appropriately gear their actions toward the two-dimensional properties of pictures.

A final issue concerns how to explain the fact that some infants in Experiment 1 directed grasping actions exclusively at the realistic photographs. Instead of looking at this kind of behavior as representing an all-or-none qualitative shift in how infants understand pictures, we view occasional grasping at depicted objects as an emergent behavior stemming from properties of the environment, infant, and the task coming together in the moment (Thelen & Smith, 1994). These properties likely include things like the real-
ism and colorfulness of the depictions, memory for specific objects and level of inhibition, and opportunities for making comparisons and the cost of exploration. Under the right circumstances, infants can be fooled into "grasping" at a depiction of an object, either because they mistake it for the real thing or because they want to further explore its properties. For example, we might expect an infant to grasp at a depicted object when the depiction is highly realistic and easily reachable, and the infant is low on inhibitory control. The idea that grasping emerges out of a combination of factors in the moment is consistent with the fact that grasping at highly realistic pictures varied both within and across infants in our experiments. Further research is needed that systematically examines how each of the factors outlined above influences the likelihood that infants will grasp at a depicted object.

In conclusion, these two experiments demonstrate that 9-month-old infants use a wide variety of behaviors when exploring a two- or three-dimensional surface. For the most part, infants direct appropriate manual behaviors (rubs and pats) toward two-dimensional surfaces and exhibit more grasp-like behaviors when presented with three-dimensional objects. Although we occasionally see what looks like grasping directed toward two-dimensional surfaces, this type of behavior is relatively rare and likely emerges from elements of the environment, infant, and task coming together in the moment.

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REFERENCES


