Published in final edited form as:
Dev Psychol. 2008 September ; 44(5): 1242–1248. doi:10.1037/0012-1649.44.5.1242.

The Relation Between Infants' Activity with Objects and Attention to Object Appearance

Sammy Perone[1], **Kelly L. Madole**[2], **Shannon Ross-Sheehy**[1], **Maeve Carey**[1], and **Lisa M. Oakes**[3]

1 *University of Iowa*

2 *Western Kentucky University*

3 *University of California, Davis*

Abstract

We examined the relation between motor skills and attention to objects features in events in which a hand acted on an object (e.g., squeezed it) that then produced a sound (e.g., squeaking). Six- to 7-month-old infants (*N* = 41) were habituated to a single event and then tested with changes in appearance and action. Infants robustly responded to changes in action, but as a group did not respond to changes in appearance. Moreover, more skilled activity with objects during naturalistic play was associated with longer looking to a change in appearance, but not to a change in action. Implications for the relation between perception and action in infancy are discussed.

Action shapes how people experience the world and come to represent its contents. For Piaget (1952), infants' understanding of objects centered on actions (e.g., rattles are to shake), and they acquire information about object properties (e.g., certain substances can change shape) through action (e.g., molding clay). Others have argued that developing action systems tune perceptual systems and make the discovery of new classes of information possible (Bushnell & Boudreau, 1993; Gibson, 1988). However, we actually know relatively little about how infants' developing ability to act on objects contributes to their developing object representations.

Adults' object representations integrate object appearance with the actions performed on those objects. Cortical areas involved in processing motor information and those involved in processing appearance information are both activated when viewing graspable, manipulable objects (i.e., tools) but not other objects (i.e., animals) (e.g., Buxbaum et al., 2005; Chao & Martin, 2000; Creem-Regehr & Lee, 2005; Rizzolatti & Craighero, 2004). Moreover, evidence from a patient with visual agnosia shows that both sensorimotor and appearance information contribute to representations of manipulable objects – this patient could recruit information about information to recognize manipulable objects (Wolk, Coslett, & Glosser, 2005). Motor areas of cortex may even be responsible for integrating information about what objects are used for (e.g., banging nails) and the actions performed on them (e.g., swinging) (Gerlach, Law, & Paulson, 2002). Thus, actions on objects seem to be fundamentally linked with object

Correspondences should be addressed to Lisa M. Oakes, Center for Mind and Brain, 267 Cousteau Pl., University of California, Davis, CA 95618 (e-mail: lmoakes@ucdavis.edu).
Author Notes
Sammy Perone, Shannon Ross-Sheehy, and Maeve Carey are at the Department of Psychology, University of Iowa. Kelly Madole is at the Department of Psychology, Western Kentucky University. Lisa Oakes is at the Department of Psychology, University of California, Davis.

appearance and may be a critical source of information in infants' developing object representations.

However, representing both object appearance and action may be a significant challenge for infants because appearance is processed by the ventral visual stream and action is processed by the dorsal visual stream. Young infants have difficulty integrating these two types of information (Kaldy & Leslie, 2003; Oakes, Ross-Sheehy & Luck, 2006) and we know little about the mechanisms by which this integration develops. Moreover, viewing small, graspable objects may induce dorsal stream processing, but viewing larger, non-graspable objects may induce ventral stream processing (Kaufman, Mareschal, & Johnson, 2003). Thus, it is unclear how young infants will represent the appearance of graspable objects in events in which actions are performed on them.

Even young infants can encode appearance information such as color and shape (see Kellman & Arterberry, 1998 for a review). However, when young infants see events in which objects that are acted on, they selectively encode the action and ignore object appearance (Bahrick, Gogate, & Ruiz, 2002). By ten months, infants can encode both object appearance and the actions performed on them (Horst et al., 2005), and they can bind this information (e.g., purple objects are squeezed) (Perone & Oakes, 2006). Thus, between 6 and 10 months 1) sensitivity to object appearance in the context of actions increases, and 2) the ability to integrate information about object appearance and action emerges. We predict that in contexts in which actions are performed on objects, actions are more salient for young infants than is object appearance.

We also predict that infants' increasing ability to act on objects is a mechanism by which object appearance becomes a salient feature in such events. Gibson (1988) proposed that infants' developing action systems provide them opportunities to discover the affordances of objects, i.e., the perceptual features that specify what actions can be performed on or with objects. Actions may serve to highlight the appearance features common across different objects that provide clues about what can be done with the object. Drinking from different cups, for instance, may highlight the common cylindrical shape, hollow cavity, and solid bottom. Indeed, infants' manual exploration of objects has been shown to be particularly important for learning about common observable properties of objects such as shape and texture (Ruff, 1982; 1984) as well as functional properties such as containment (MacLean & Schuler, 1989).

We examined how 6- to 7-month-old infants' activity with objects in a naturalistic play setting with one set of objects was related to their attention to object appearance in events involving actions performed on a different set of objects. At this age, infants begin to sit independently, allowing them to maintain balance while extending the arms away from the body and more adequately reach for and grasp objects (Adolph & Berger, 2006). The onset of independent sitting is accompanied by a general increase in activity with objects (Spencer, Vereijken, Frederick, & Thelen, 2000). Thus, this is an ideal age for examining the relation between activity with objects and attention to object appearance.

Preliminary Study

Our first prediction was that information specifying *action* is more salient for young infants than is information specifying appearance. Although Bahrick et al. (2002) observed that actions (e.g., brushing hair) were more salient for infants than were appearance features (e.g., the hairbrush, the particular actress), we needed to confirm that this pattern is general and observed with our stimuli. Therefore, in a preliminary study we assessed the responding of 26 7-month-olds (M = 223.23 days, SD = 8.68; 12 girls and 14 boys) to changes in object appearance and action. Using the procedures described below (see Figure 1), infants were habituated to a single event in which a hand acted on an object and a sound was produced. Thus, *action* in our events refers to the actions and the resulting sounds. Infants then received two test trials in a counterbalanced order: one that involved a novel appearance and one that involved novel action. In a final test trial all features were novel.

Compared to the baseline (a trial with the familiar item presented after the habituation criterion was met), infants dishabituated to a novel appearance t (25) = 2.34, p = .0.3, d = .46, to novel action, t (25) = 4.57, $p < .001$, d = .90 (see Figure 2) and when all features were novel, t (25) = 5.18, $p < .001$, d = 1.25. However, infants dishabituated significantly more to novel action than to a novel appearance, t (25) = 2.74, p = .01, d = .59. Moreover, 81% (21) of the infants had dishabituation scores greater than 1.0 s to novel action but only 62% (16) of the infants had dishabituation scores greater than 1.0 s to a novel appearance. Thus, infants treated the action (and accompanying sound) as more salient than appearance in these events. It is possible that the changes in action are more discriminable (perhaps because of a lack of psychophysical equivalence) than are changes in appearance. However, by 10 months infants do not respond differently to these two types of information in these events (Horst et al., 2005). Thus, even if changes in action are discriminable than are changes in appearance, over development the difference in salience between the two types of features decreases. Thus, the important developmental question is not whether infants *in general* are more interested in action or appearance, but rather what promotes the increase in salience of appearance in contexts in which action is initially more salient.

Method

Participants

The final sample included 41 healthy, full-term infants approximately 6 months of age (M = 201.24 days, SD = 7.96; 22 girls, 19 boys; 34 infants were white; 2 were Asian, 2 were mixed race, and 3 did not report race), recruited using our usual procedures (Perone & Oakes, 2006). All of the 39 mothers who reported education level had graduated high school and 24 had at least a bachelor’s degree. Six additional infants were excluded because of maximum looking duration during the baseline test (n = 2), fussiness (n = 2), or experimenter error (n = 2). Note that the infants were younger than those in the preliminary study. Although those infants found action (and the accompanying sound) more salient, they did significantly dishabituate to a novel appearance. We tested infants a few weeks younger to increase the variability in infants’ response to the tests, thus providing a better context for examining the relation between action and perception.

Stimuli

The stimulus events consisted of a 7 s sequence in which a hand reached for and acted on an object, producing a sound. The hand then retreated and the sequence repeated for up to 35 s. When viewed on a 43.20 cm computer monitor, the objects were approximately 10 cm wide by 9 cm tall (subtending 6 degrees by 5.25 degrees visual angle at a viewing distance of 100 cm). Five different types of actions (each accompanied by a different sound) (shaking producing rattling, squeezing producing squeaking, rolling producing clicking, inverting producing mooing, and pulling producing whistling) were crossed with 5 object appearances (purple sphere, yellow cube, pink tube, multicolored pyramid, and multicolor sphere stack) to generate 25 unique events.

Apparatus, design, and procedure

Infants participated in three tasks. To determine the influence of sitting on any observed relations, the first task was the *Sitting Assessment*. An experimenter placed the infant on a blanket on the ground and slowly released his or her hands from the infant when he or she determined that the infant was secure, remaining nearby to protect against falling. Infants were videorecorded for 30 s. One infant was too fussy to complete this task and another infant's session was not recorded.

Next, using a habituation procedure, we assessed infants' memory for object appearance and action. Infants sat on a parent's lap 100 cm from a 43.20 cm computer monitor. A black curtain hung from the ceiling with openings for the monitor, speaker, and video camera. To reduce bias, parents wore occluding glasses and listened to classical music via headphones. A trained observer sat in an adjacent room and used specialized software (Cohen, Atkinson, & Chaput, 2000–2002) to present stimuli and record looking time on a Macintosh G4 computer.

Prior to each trial, a green circle loomed (and chirped) at the center of the monitor. When the infant fixated this attention-getter, the observer initiated a trial and pressed and held a computer key (to record the looking duration) when he or she judged the infant was fixating the stimulus. Trials ended when the infant looked away for 1 s following at least 1 s of looking, or until 35 s had elapsed (the trial was repeated if no looking was recorded in the first 10 s). A second trained observer recorded looking times from video for 27% of the infants. Agreement between the observers was high, $r = \geq .99$, and the mean difference in looking on each trial was low, $M = \leq .56$ s.

Each infant was first presented with one randomly selected event until their looking time on any block of 3 consecutive trials decreased to 50% of their looking time on the first 3 trials, or until 18 trials were presented. Once this criterion was met, the familiar event was presented once again. Looking to this event served as a baseline for comparison to the novel items. Next, infants received a test involving a novel appearance and a test involving novel action, order counterbalanced across infants. An infant familiarized with a purple sphere that squeaked when squeezed, for example, might see a pink tube squeak when squeezed (i.e., novel appearance) and the purple sphere click when rolled (i.e., novel action). The fourth test involved novel action and a novel object appearance. On the last trial, we examined infants' general interest in novelty with an event that involved a dog running. All infants completed this task.

Finally, we assessed infants' manual activity with objects in a *natural play session*. Parents sat on the ground, behind their infants, providing support as needed (e.g., held them between their legs). Although the level of support provided varied, all parents kept their infants from falling. Parents did not interact with their infant or toys. All infants could use their arms to reach for objects. Thus, any differences that we observe in infants' activity with objects is not due to large differences in postural support. An experimenter placed four objects (see Figure 3) in close proximity to the infant, between and next to the legs and just beyond the feet. The location of particular objects was determined randomly. Thus, the particular object that was the closest object was different for each infant. We videotaped infants playing for 2 minutes. One infant was too fussy to complete this session, and 5 infants' sessions were not recorded.

Coding

A trained observer watched each infant's sitting session and recorded the following durations: 1) experimenter's hands on the infant (e.g., supporting a leaning infant), 2) infant's bottom off the floor (e.g., arching his or her back), 3) leaning forward on the leg(s), and 4) bracing by placing hand(s) on the floor or legs. The duration of independent sitting was calculated from periods of time for which none of these behaviors were present. A second trained observer coded 25% of the infants. Agreement between the two coders was high, $r = .94$, and average differences were low, $M = 3.01$ s, SD = 3.68, for the 30 s session.

We coded the play session for three object-directed behaviors: 1) the number of times an infant successfully obtained an object–i.e., grasping, picking up an object and holding it above the ground for at least 1 s (two consecutive successes to the same object were counted as separate successes only when the infant let go and re-grasped the object prior to lifting the object above the ground for a second time), 2) latency to the first successful grasp (i.e., the time between the beginning of the session and the first recorded successful grasp), 3) the duration that infants held each object that they successfully attained. Two trained coders independently coded 25% of these sessions and had 100% agreement.

Each of these behaviors is well supported by findings in the literature. The onset of reaching is associated with a dramatic increase in grasping and holding objects (Spencer et al., 2000). Picking up and holding objects are also common measures of infants' activity with objects and have been associated with perceptual development (e.g., Eppler, 1995). Thus, obtaining objects is reflects motor developments in reaching and is a gross measure of activity. Latency to first success may reflect an infant's ability to organize an exploratory response with development. It decreases with age (Ruff, 1986), suggesting that infants become able to more quickly organize their exploratory response. In addition, Ruff (1986) found that infants' latencies to pick up familiar and novel objects did not differ, suggesting that latency reflects engagement with and not learning about objects. Finally, durations of holding and manual exploration of objects provide infants information about observable object properties such as shape and texture (Ruff, 1984) and non-observable properties such as substance (Rochat, 1987).

Results

We evaluated the data in several steps. To increase power, each set of analyses was conducted with all the infants who completed the relevant tasks.

Relation between levels of activity with objects and other variables

We first examined the relation between motor development and other developmental differences (see Table 1). None of our measures of activity was significantly correlated with age in days or general habituation measures (i.e., looking during initial block, number of trials to habituate, or looking to the dog post-test). Although others have observed a relation between sitting ability and manual activity with objects (e.g., Spencer et al., 2000), in our sample the duration of independent sitting was unrelated to any of our measures of activity. Note, therefore, that although such measures are generally associated with age (i.e., as infants get older they get better at sitting, manipulating objects, habituation more efficiently), within the narrow age range of the current study, variability in any of these measures do not reflect variability in age. Thus, we can examine correlations between those measures and our measures of interest without the concern that those correlations actually reflect associations with age.

Group responding to changes in appearance and action

As we observed in the preliminary study, infants significantly dishabituated more to novel action than to a novel appearance, $t(40) = 5.33$, $p < .001$, $d = .78$ (see Figure 2). Unlike our preliminary study, these younger infants did not significantly dishabituate to a novel appearance, $t(40) = 1.51$, $p = .14$, $d = .27$. They did significantly dishabituate to a novel action, $t(40) = 5.79$, $p < .001$, $d = 1.21$. Only 52% (21) of infants had dishabituation scores to a novel appearance that were greater than 1.0 s. In contrast, 76% (31) of infants had dishabituation scores to a novel action that were greater than 1.0 s. Thus, as we observed in our preliminary study, infants were less responsive to novel appearances than to novel actions. In two separate samples, therefore, we confirmed our first prediction that in such events action (and it's accompanying sound) is more salient for infants than is object appearance.

Relation between individual differences in activity with objects and attention to appearance

Our main analyses evaluated our prediction that infants' looking to novel appearances, but not their looking to novel actions, would be related to individual differences in activity with objects (age was not related to their responding to either test, *r* (39) = .22, novel appearance test, *r* (39) = −.15, novel action test).

First, we conducted simple, or zero-order, correlations (see Table 2). Infants' looking to a novel appearance was significantly related to each measure of activity; infants who had more successful grasps, held objects for longer, and were quicker to pick up the first object looked longer at the test involving a novel appearance. This result confirmed our second prediction: Infants who were more active and engaged looked longer at a novel appearance. No such relations were observed between activity and infants' looking to novel actions. To confirm that this pattern of correlations reflected the relation between the specific variables of interest, and not other potentially mediating variables, we also conducted partial correlations controlling for sitting ability (i.e., duration of independent sitting) and general interest in novelty (i.e., duration of looking during the post-test) (see Table 2). Zero-order correlations do not take into account any shared variance due to other factors; partial correlations allow us to examine the relation between the two variables while controlling for the variation due to other variables. Partial correlations, therefore, allow us to determine whether the variables of interest are related above and beyond any shared variation with other factors.

We controlled for sitting ability to addresses the possibility that the observed relation was a function of general motor development. We controlled for interest in novelty to address the question of whether activity with objects was related to interest in a novel appearance above and beyond infants' interest in novelty in general. [Preliminary analyses revealed partial correlations controlling for age did not change the results.] The partial correlations confirmed the zero-order correlations and revealed that the effects between activity and interest in a novel appearance remained even when controlling for these two abilities (see Table 2). The identical partial correlations conducted on infants' interest in novel actions did not reveal any significant relations.

The corresponding analyses with measures of sitting rather than measures of activity were not significant. Therefore, activity, but not sitting, is related to attention to appearance. Thus, this relation is specific to infants' activity with objects and does not reflect a general effect of motor development on infants' attention to the features in these events.

These correlations were corroborated by a series of comparisons of more and less active infants. Fifteen infants were classified as active—they were above the median in the number of successes and duration holding objects, and below the median on their latency to the first success. These infants significantly dishabituated to a novel appearance ($M = 6.09$, $SD = 10.47$), $t(14) = 2.25$, $p = .04$, $d = .56$, and novel action ($M = 15.91$, $SD = 13.21$), $t(14) = 4.66$, $p < .001$, $d = 1.21$. The 20 infants classified as less active failed to dishabituate significantly to a novel appearance ($M = .17$, $SD = 8.62$), $t(19) = .09$, *ns*, but they did dishabituate to a novel action ($M = 10.97$, $SD = 13.79$), $t(19) = 3.56$, $p = .002$, $d = .80$. In addition, the active group had marginally significantly greater dishabituation to a novel appearance than did the less active group, $t(33) = 1.83$, $p = .08$, $d = .80$. The two groups did not differ in their dishabituation to novel actions, $t(33) = 1.07$, *ns*.

Discussion

This experiment confirmed our predictions. In events depicting an action on an object, the action (and its sound) was more salient for young infants than was object appearance. In addition, infants' own activity with one set of objects predicted their response to a novel appearance in events involving a different set of objects. These results implicate infants' emerging action systems as a mechanism by which they take their first steps toward integrating information about action and object appearance.

These findings are consistent with a growing literature revealing that action is an integral component of adults' representations of graspable objects (e.g., Creem-Regehr & Lee, 2005; Wolk et al., 2005). Moreover, this study is consistent with the theoretical ideas of Gibson (1988) and Bushnell and Boudreau (1993) who proposed that developmental changes in infants abilities to act on objects makes the discovery of new classes of information possible. Increases in infants' activity with objects is also thought to tune their perceptual systems to the link between the perceptual features of objects and the actions those objects afford.

A number of studies have shown that infants' actions are related to their attention to and learning of appearance features. Needham (2000), for instance, found that infants' activity with objects was related to their ability to use surface features to make edge assignments and segregate spatially contiguous objects. Ruff (1984) found that infants learned commonalities across different objects such as shape and texture via their manual exploration. In fact, Ruff (1982) found that infants' manual exploration of objects was necessary to learn the common shape across different objects. Thus, infants' activity with objects is a crucial source of information about a variety of observable object properties. This study adds to the extant literature showing that infants' manual activity with objects is a mechanism by which appearance features become relevant for infants. This study takes one additional step in showing that infants' activity with objects is related to their attention to appearance features in events in which objects are acted on.

Furthermore, linking object appearance and the types of actions performed on objects is crucial for recognizing objects (Wolk et al., 2005), and young infants' actions on objects may significantly contribute to their ability to integrate information about object appearance and action later in infancy (Perone & Oakes, 2006). In particular, actions may help infants learn important links between object appearance and how objects are typically used or what objects can do. Indeed, exploring objects can also facilitate children's categorization of objects by highlighting the relations between objects' appearances and their uses (Kemler Nelson, 1999). Importantly, the mechanisms by which infants' developing action systems impact their knowledge about objects is almost certainly a bi-directional one. Actions alter what infants attend to, perceive, and remember about objects, and their representations in turn contribute to what actions they perform on objects (see Corbetta, Thelen, & Johnson, 2000).

Finally, these results provide important information about the generality of the mechanism linking action and object representation. Certainly, it would not be surprising if the skill with which infants acted on objects was related to the their attention to the appearance of *those same objects*. We observed here, however, that infants' activity with one set of objects predicted their learning about features of a different set of objects (see also Needham, 2000; Eppler, 1995). Thus, infants' activity with objects is broadly related to the kind of information to which they attend when encountering objects, suggesting that a general mechanism underlies the emerging ability to act on objects and how objects are perceived and represented.

In summary, these findings contribute to our understanding of developmental changes in infants' representation of different kinds of features in events involving actions on objects. In particular, we showed that infants' representation of the features of such events is related to their activity with objects. Establishing this type of relation is key to understanding mechanisms of developmental change. Thus, these results contribute to our understanding of the complex relation between perception and action during infancy, and may reveal the origins of how action and object identity are represented in adults.

Acknowledgements

This research and preparation of this manuscript were made possible by NIH grants HD49840, HD49143 and MH64020 awarded to LMO; SRS was funded by predoctoral and postdoctoral NRSAs (HD055040, MH068934). We thank Shaena Stille, Kristine Kovack-Lesh, and the undergraduate students in the Infant Perception and Cognition Laboratory at the University of Iowa for their help with this project.

References

Adolph, KE.; Berger, SE. Physical and motor development. In: Bornstein, MH.; Lamb, ME., editors. Developmental science: An advanced textbook. 5. Hillsdale, NJ: Erlbaum; 2006.

Bahrick LE, Gogate LJ, Ruiz I. Attention and memory for faces and actions in infancy: The salience of actions over faces in dynamic events. Child Development 2002;73:1629–1643. [PubMed: 12487483]

Bushnell, Boudreau. Motor development and the mind: The potential role of motor abilities as a determinant of aspects of perceptual development. Child Development 1993;64:1005–1021. [PubMed: 8404253]

Buxbaum LJ, Saffran EM. Knowledge of object manipulation and object function: Dissociations in apraxic and nonapraxic subjects. Brain and Language 2002;82:179–199. [PubMed: 12096875]

Chao LL, Martin A. Representation of manipulable, man-made objects in the dorsal stream. NeuroImage 2000;12:478–484. [PubMed: 10988041]

Cohen, LB.; Atkinson, DJ.; Chaput, HH. Habit 2000: A new program for obtaining and organizing data in infant perception and cognition studies. Austin, TX: The University of Texas; 2000–2002. (Version 1.0) [Computer Software]

Corbetta D, Thelen E, Johnson K. Motor constraints on the development of perception-action matching in infant reaching. Infant Behavior and Development 2000;23:351–374.

Creem-Regehr SH, Lee JN. Neural representations of graspable objects: Are tools special? Cognitive Brain Research 2005;22:457–469. [PubMed: 15722215]

Eppler MA. Development of manipulatory skills and the deployment of attention. Infant Behavior and Development 1995;18:391–405.

Gerlach C, Law I, Paulson OB. When action turns into words. Activation of motor-based knowledge during categorization of manipulable objects. Journal of Cognitive Neuroscience 2002;14:1230–1239. [PubMed: 12495528]

Gibson EJ. Exploratory behavior in the development of perceiving, acting, and the acquiring of knowledge. Annual Review of Psychology 1988;39:1–41.

Horst JS, Oakes LM, Madole KM. What does it look like and what can it do? Category structure influences how infants categorize. Child Development 2005;76:614–631. [PubMed: 15892782]

Kaldy Z, Leslie A. Identification of objects in 9-month-old infants: Integrating ‘what’ and ‘where’ information. Developmental Science 2003;6:360–373.

Kaufman J, Mareschal D, Johnson MH. Graspability and object processing in infants. Infant Behavior and Development 2003;26:516–528.

Kellman, PJ.; Arterberry, ME. The cradle of knowledge: Development of perception in infancy. Cambridge, MA: MIT Press; 1998.

Kelmer Nelson DG. Attention to functional properties in toddlers’ naming and problem-solving. Cognitive Development 1999;14:77–100.

MacLean DJ, Schuler M. Conceptual development in infancy: The understanding of containment. Child Development 1989;60:1126–1137. [PubMed: 2805891]

Needham A. Improvements in object exploration may facilitate the development of object segregation in infancy. Journal of Cognition and Development 2000;1:131–156.

Oakes LM, Ross-Sheehy S, Luck SJ. Rapid development of feature binding in visual short-term memory. Psychological Science 2006;17:781–787. [PubMed: 16984295]

Perone S, Oakes LM. It clicks when it is rolled and it squeaks when it is squeezed: What 10-month-old infants learn about object function. Child Development 2006;77:1608–1622. [PubMed: 17107449]

Piaget, J. The Origins of Intelligence in Children. New York, NY: International Universities Press, Inc; 1952.

Rizzolatti G, Craighero L. The mirror neuron system. Annual Review of Neuroscience 2004;27:169–192.

Rochat P. Mouthing and grasping in neonates: Evidence for the early detection of what hard or soft substances afford for action. Infant Behavior and Development 1987;10:425–449.

Rochat P. Object manipulation and exploration in 2- to 5-month-old infants. Developmental Psychology 1989;25:871–884.

Rochat P, Goubet N. Development of sitting and reaching in 5- to 6-month-old infants. Infant Behavior & Development 1995;18:53–68.

Ruff HA. Role of manipulation in infants' responses to invariant properties of objects. Developmental Psychology 1982;18:682–691.

Ruff HA. Infants' manipulative exploration of objects: Effects of age and object characteristics. Developmental Psychology 1984;20:9–20.

Ruff HA. Components of attention during infants' manipulative exploration. Child Development 1986;57:105–114. [PubMed: 3948587]

Spencer JP, Vereijken B, Frederick JD, Thelen E. Posture and the emergence of manual skills. Developmental Science 2000;3:216–253.

Wolk DA, Coslett HB, Glosser G. The role of sensory-motor information in object recognition: Evidence from category-specific visual agnosia. Brain and Language 2005;94:131–146. [PubMed: 15896389]

Yoon EY, Humphreys GW. Direct and indirect effects of action on object classification. Memory & Cognition 2005;33:1131–1146.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

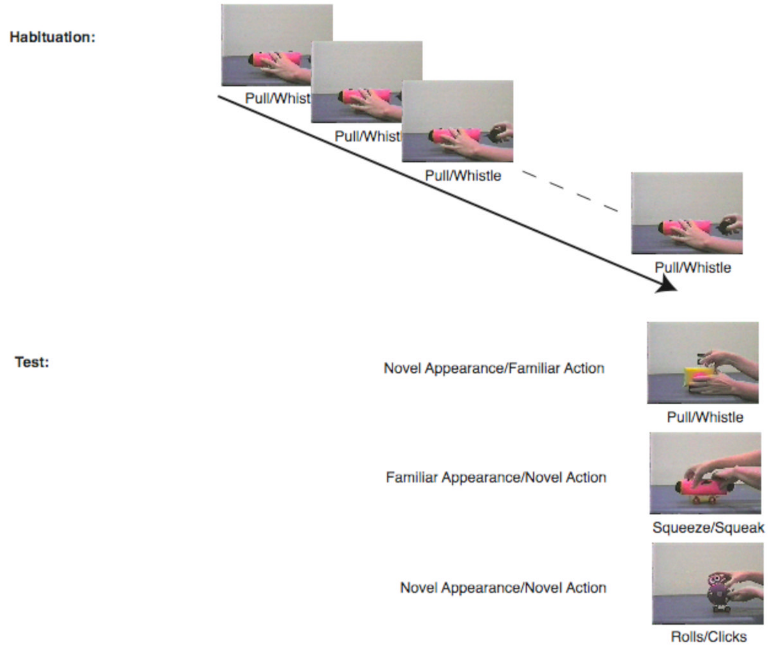

Figure 1.
The experimental design of the main task in both the preliminary and main Experiments.

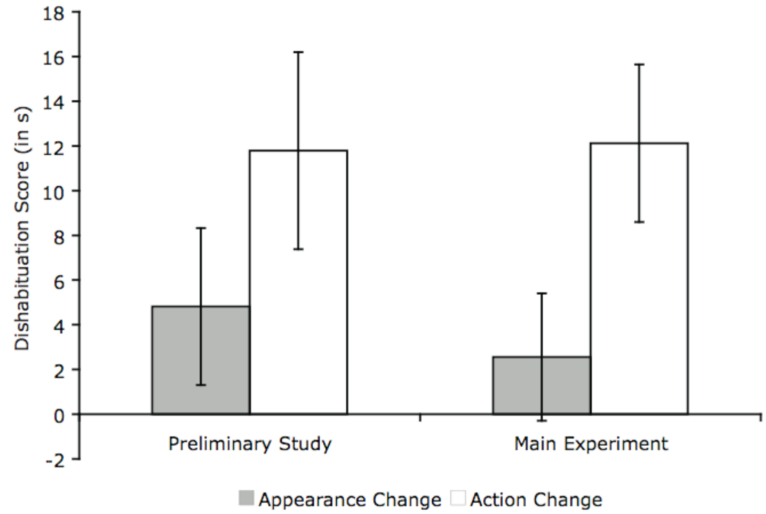

Figure 2.
Mean dishabituation scores (in s) to the tests involving a change in appearance (dark gray bars), a change in action (white bars), and a change in both appearance and action (light gray bars) in each the preliminary and main experiments. Error bars represent 95% confidence intervals.

Figure 3.
An infant in the object exploration task.