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#### **Authors**

Oakes, Lisa M.  
Perone, Sammy  
Madole, Kelly L.

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# How Outcomes of Actions Influence Infants' Representation of Those Actions

**Lisa M. Oakes (lmoakes@ucdavis.edu)**

UC Davis Center for Mind & Brain, 267 Cousteau Place  
Davis, CA 95618 USA

**Sammy Perone (Sammy-Perone@uiowa.edu)**

Department of Psychology, University of Iowa  
Iowa City, IA 52242 USA

**Kelly L. Madole (kelly.madole@wku.edu)**

Department of Psychology, Western Kentucky University  
Bowling Green, KY 42101 USA

## Abstract

Three experiments examined how the outcomes of actions influences 10-month-old infants' ( $N = 56$ ) representation of those actions and the objects on which they are performed in dynamic, multimodal events. In each experiment, infants were habituated to events in which a colorful novel object was manipulated by a hand. Infants learned that some actions produced outcomes while others did not (Experiment 1), but did not learn that objects with a particular appearance produced outcomes (Experiment 2). Infants did learn the isolated actions and appearances even when the actions did not produce an effect (Experiment 3). Together, these results suggest that how infants learn about and represent the *action* performed on objects depends, in part, on whether or not that action is the cause of a salient outcome.

**Keywords:** Infant cognition; object representation; causal perception; perception of action; visual habituation.

## Introduction

Infants' representation of objects and object features has become a central focus in cognitive development. Researchers have documented developmental changes in infants' ability to remember features such as color, shape, and texture of objects, as well as how movement changes infants' attention to, perception of, and memory for objects (see Kellman & Arterberry, 1998, for a review). This work has revealed that young infants have impressive abilities to represent object features, and that these representations change dramatically over the first year of life. Recently, infants' representation of dynamic features—such as causal roles, functions, and goals or intentions—has been the focus of intense interest (e.g., Horst, Oakes, & Madole, 2005; Rakison, 2005a, 2006; Woodward, 1998).

Some researchers have argued that attention to these kinds of features reflects a shift from perceptual representations to conceptual representations (Mandler, 2004), but the usefulness of this assertion has been questioned (Madole & Oakes, 1999). In particular, it is not clear that selective attention to such features reflects the privileged status of “conceptual” features. Indeed, it has been argued that the distinction between perceptual and conceptual features or categories is artificial, and that the two sources or kinds of

information are inextricably intertwined (Goldstone & Barsalou, 1998; Madole & Oakes, 1999; Rakison, 2005b).

Nonetheless, in some contexts infants do find dynamic, intermittent features such as object sound, function, and movement or action more compelling than relatively static constant features such as object color or shape (Horst et al., 2005; Robinson & Sloutsky, 2004). However, the source of this differential salience is not well understood. Movement may attract attention simply because it is associated with low-level perceptual features known to automatically attract attention such as abrupt onset and transients (e.g., Yantis & Jonides, 1990). Such factors certainly contribute to the salience of these features.

In addition to these basic, low-level factors, however, infants' developing perception of causality may contribute to the salience of some object features. By 10 months, infants use spatial and temporal features of events to differentiate causal from non-causal relations (Oakes, 2003). Because they perceive causal events as different from non-causal events, parts of events that appear to be the causes of interesting outcomes may be particularly attention-grabbing for infants. Indeed, infants are especially sensitive to the features of causal agents in events (Cohen & Oakes, 1993; Rakison, 2005a).

Importantly, this selective attention to causes need not reflect deep conceptual understanding of (or inferences about) causal mechanisms. Infants' sensitivity to the spatiotemporal conditions that differentiate causal agents from non-causal agent (i.e., actors in non-causal events) may reflect their *perception* of causality based on perceived spatiotemporal contiguity. This perceptual ability may be the foundation of the deeper conceptual understanding of causes and their effects that is shown by older individuals.

A consideration of infants' attention to causal features can illuminate another aspect of infants' object representations: By 10 months, infants treat *object function*—defined as an action performed on an object that is associated with an outcome—as an important feature of objects. Under some conditions infants selectively attend to function over the surface features of objects (Horst et al., 2005), and they use function as the basis of categorization (Booth & Waxman,

2002). However, despite the importance of object function, we know little about how infants represent function. One possibility is that what infants actually represent are actions that cause outcomes. This assertion is supported by research showing that 10-month-old infants associate the *actions* performed on objects with the surface features of objects (e.g., you can squeeze round, purple objects), but they do not associate the *outcomes* with the surface features of objects (e.g., round purple objects squeak when acted on) (Perone & Oakes, 2006). In addition, *causes* are thought to be central to how adults and infants represent and categorize objects (Ahn, Kim, Lassaline, & Dennis, 2000), and actions

that produce outcomes are key to how objects are represented in the adult brain (Martin, 2007).

We tested the role of outcomes on infants' perception of actions in 3 experiments. In Experiment 1, we examined infants' sensitivity to the association between *causal* and *non-causal* actions. That is, we asked whether infants would learn that some actions produce outcomes and others do not. In Experiment 2, we investigated infants' differentiation between *functional* and *non-functional* objects. That is, we asked whether infants would learn that objects with one appearance produced outcomes when acted on but object with other appearances do not produce outcomes when acted on. Finally, in Experiment 3, we asked whether infants can learn the isolated object appearances and actions in events in which the action is ineffective—that is, it does not produce a salient outcome.

## General Methods

### Participants

Fifty-six healthy, full-term typically developing 10-month-old infants participated; 20 in each of Experiments 1 and 2, 16 in Experiment 3. The average age of the infants was 304.91 days,  $SD = 7.59$ , and there were 30 girls (approximately equal boys and girls in each experiment).

### Apparatus

A Macintosh G4 or G5 computer was used to present the stimuli and to record infants' looking time. Stimuli were presented on a 37 cm (w) X 27 cm (h) region of a CRT or LCD monitor. Infants were recorded using a low-light security camera located directly beneath the center of the monitor. A black curtain hung from ceiling to floor blocking infants' view of the equipment. Holes in this curtain revealed the monitor and the low-light camera.

### Stimuli

The stimuli were digitized movies of videotaped events in which a hand performed one of four actions (squeezing, rolling, inverting, or pulling a part away from the body of the object) on an object with one of four appearances (see Figure 1).

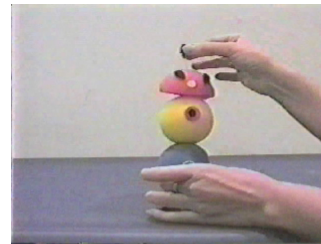


Figure 1. An example of the stimuli used in all experiments

Each event had the following sequence: an object appeared stationary for 1 s, a hand then appeared and acted on the object for 5 s, the hand then retreated and the object remained stationary for 1 s. This sequence could be looped to play continuously for 35 s. At a viewing distance of 100 cm, the objects subtended a visual angle of between 3.64 and 8.72 degrees by between 4.00 and 6.54 degrees.

For Experiments 1 and 2, an outcome (sound) was produced (squeaking, clicking, mooing, and whistling) when an action was performed on an object. For example, when the hand squeezed the spherical purple object it squeaked. The action, appearances, and outcomes were completely crossed to create 64 events. Thus, the association between particular actions and outcomes, particular actions and appearances, or between particular appearances and outcomes were arbitrary.

### Procedure

For each experiment, infants were seated on a parent's lap approximately 100 cm in front of a computer monitor (parents wore occluding glasses in all experiments, and also listened to music through headphones in Experiments 1 and 2). A trained observer, seated out of view, observed infants on a monitor. Before each trial, a green circle loomed in the center of the monitor accompanied by a chirping sound. When the infant looked at this attention-getting stimulus, the observer pressed one computer key that simultaneously ended the attention-getter and presented the stimulus and then pressed and held another computer key when infant looked at the monitor. The stimulus remained on the screen until the infant looked at the stimulus for at least 1 s before looking away for at least 1 s, or 35 s had elapsed. If no looking was recorded in the first 10 s, the trial ended and was repeated. A second trained observer recorded the looking times for 25% of the infants from video records of the sessions. Across the experiments, mean inter-observer correlation for duration of looking on each trial was high,  $r = .998$ , and the absolute difference between observers was low,  $M = .45$  s.

In each experiment, infants were habituated to one (Experiment 3) or two (Experiments 1 and 2) events. Habituation continued until infants' looking time decreased to 50% of their looking during the first block of trials, or until 20 trials were presented. In each experiment, infants habituated to the familiar event(s) and significantly dishabituated to a completely novel event presented last (see Table 1). Following habituation, infants were tested with a series of novel events. The particular habituation and test events will be described separately for each Experiment.

**Table 1: Looking times during habituation and test for Experiments 1-3**

Experiment	Trial		
	First	Familiar Test	Novel Test
1	22.10 (13.34)	7.14 (4.75)	20.93 (11.09)
2	19.18 (10.60)	6.49 (4.64)	23.11 (10.99)
3	18.23 (10.01)	5.74 (4.44)	14.71 (8.36)

Note. Means are in s. Standard deviations are in parentheses.

### Experiment 1

Perone and Oakes (2006) reported that infants associated actions and object appearances, but that infants failed to associate actions with particular outcomes, suggesting that the *specific* outcome is not central to how infants represent actions. Note that actions can be causes even if they are not associated with a specific outcome—shaking might produce rattling, whistling, or clicking. What might be relevant is that the action produces *an* outcome, not that it is associated with a *particular* outcome. Indeed, Cohen and Oakes (1993) found that 10- to 12-month-old infants attended to the agents but not recipients in causal launching events; infants did not attend to the identity of either agents or recipients in noncausal launching events.

If this pattern reflects a general property of infants' attention to and representation of events, what may be relevant in the present context is that the action produces an outcome, not that it produces a specific outcome. We tested this hypothesis in Experiment 1 by habituating infants with two events involving two different actions; one action produced an effect (i.e., squeaking), the other did not (i.e., the event was silent). Following habituation, we tested infants on two *switched* events; one in which a previously ineffective action now produced an outcome and another in which a previously effective action did not produce an outcome. We reasoned that if infants learn that some actions produce outcomes (even though they are insensitive to the particular outcome associated with an action), they should dishabituate when a previously non-causal action now produces an outcome as well as when a previously causal action now does not result in an outcome.

### Method

Twenty infants were habituated to two events involving the same object appearance but different actions. One action always produced an outcome (the +outcome event); the other action never produced an outcome (the -outcome event). For example, infants might see the purple spherical object being squeezed and squeaking on half the trials and the purple spherical object being pushed and no sound occurring the other half of the trials. Thus, infants were habituated to essentially one causal action and one non-causal action. During each block of 4 habituation trials, infants received two trials with each of the two habituation events (note that many different pairs of habituation events were used, and thus the responding of the group of infants reflects their general ability to learn this relation, not their

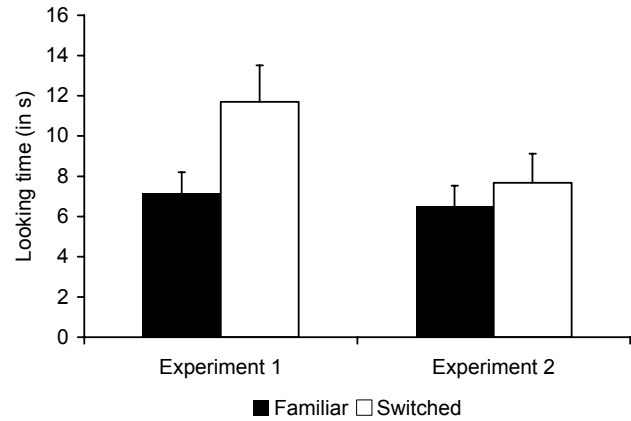


Figure 2. Infants' looking time to the familiar test and the average of the two switched events in Experiments 1 and 2.

ability to learn the relation in one pair of stimuli). The order within blocks was random. Habituation was evaluated by comparing non-overlapping blocks of 4 trials, ensuring that infants received equal number of presentations with the two familiar events. Infants habituated in 13.0 trials on average.

Immediately following habituation, four test trials were presented. The familiar event was presented on the first trial. Then two *switched* events were presented, order counterbalanced across infants. In one switched event, the previously effective action (i.e., the action in the +outcome event) was presented in an -outcome event and in the other the previously ineffective action (i.e., that in the -outcome event) was presented in an +outcome event. Essentially, infants were habituated to one causal action and one non-causal action, and then they were tested with the causal action in a non-causal event, and the non-causal action producing an effect. The fourth test was completely novel.

### Results

Initial analyses revealed that infants' looking to the two switch events did not differ significantly. To increase power, we averaged looking across those two events and compared infants' dishabituation to these events by comparing their average looking time to the two switched tests to their looking time to the familiar test. Infants significantly dishabituated to the switched tests,  $t(19) = 2.92, p = .009$  (see Figure 2), indicating that they detected the association between the action and whether or not it produced a sound (separate t-tests confirmed that infants dishabituated to both switch tests).

### Discussion

Experiment 1 showed that 10-month-old infants can learn that some actions cause outcomes and others do not, despite the fact that previous results have shown that at 10 months infants fail to associate a particular outcome with a particular action (Perone & Oakes, 2006). In Experiment 1, 10-month-old infants associated a particular action with the production of an effect (in this case a sound) and a different action with the failure to produce an effect. They dishabituated when a

previously ineffective action produced an outcome or when a previously effective action failed to produce an outcome.

## Experiment 2

Experiment 1 revealed that infants learn that particular actions are associated with outcome. It is possible, however, that infants learn that any feature of events can be associated with outcomes. In Experiment 2 we tested infants' sensitivity to the association between object appearance and the outcomes of actions—i.e., whether they will learn that some objects are functional (i.e., produce an outcome when acted on) and other objects are non-functional.

### Method

This experiment was identical in all respects to Experiment 1 except that the two events had the same action, and one appearance was associated with an outcome (the +outcome event) and the other appearance was not (the -event). For example, both events might involve squeezing, but purple spherical objects whistle and pink oblong objects are silent when squeezed. The 20 infants tested habituated in 15.4 trials on average.

### Results

Once again, infants' responding to the two switched tests did not differ; they were therefore averaged to increase power. The main analysis evaluated infants' dishabituation (or lack of dishabituation) to the switched tests. Unlike Experiment 1, infants in Experiment 2 failed to dishabituate to the switched test event,  $p = .46$  (see Figure 2) (individual comparisons of each switched test revealed that infants failed to dishabituate to both items). Thus, infants did not associate object appearance with whether or not the action produced an effect (a sound).

### Discussion

Experiment 2 ruled out the possibility that infants simply associate any distinguishing feature with whether or not actions produce an interesting, salient effect. In Experiment 2, like in Experiment 1, half of the events involved an effect. In Experiment 2, however, the same action occurred on each trial. The distinguishing feature that was associated with whether or not there was an outcome was the appearance of the objects. Despite the fact that the objects were highly discriminable and could be differentiated using any of several features (e.g., color, shape, presence of specific parts), infants failed to link those features with whether or not the event was causal—or whether or not the action produced an outcome. In other words, infants did not learn that some objects are functional (i.e., produce an effect when acted on) and other objects are nonfunctional (i.e., fail to produce an effect when acted on).

This pattern of results is particularly striking because Perone and Oakes (2006) observed that at 10 months infants do associate specific actions with specific object appearances. That is, infants learned that some objects could be acted on in

a particular way (e.g., rolled) and other objects were acted on in another way (e.g., inverted). Here, we observed that infants did not learn that when two different looking objects were acted on in the same way, one object produced an outcome and the other did not. Thus, infants can associate object appearances with some aspects of the action, but they are insensitive to the association between appearance and the results of that action.

It is possible, however, that infants fail to represent actions and/or appearances when the actions do not produce an outcome. Therefore, in Experiment 3 we tested infants' sensitivity to changes in just appearance or in just action when the actions did not produce a salient outcome.

## Experiment 3

### Method

Sixteen infants were presented with a single event until their looking time on any block of 3 trials was 50% of their looking on the first block of 3 trials. The event was identical to those used in the previous experiments, except that when the action was executed it did not result in an outcome (i.e., a sound). Infants habituated in 7.9 trials on average. Immediately after habituation, infants were tested with the familiar item to provide a baseline for their response to the novel items. Then, they were tested with two new items—one with a new appearance and familiar action and the other with a new action and a familiar appearance (in both of these events, the action did not produce an outcome). The order of these two items was counterbalanced across infants. The last test was an event with a new action and a new appearance (again, no outcome was produced by the action).

### Results

Looking to the familiar, appearance change and action change tests are presented in Figure 3. Infants dishabituated to both changes,  $t(15) = 5.45$ ,  $p < .001$ , appearance change, and  $t(15) = 3.88$ ,  $p = .001$ , action change.

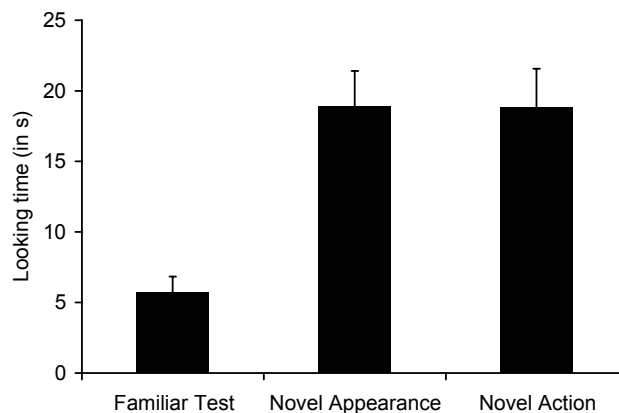


Figure 3. Looking times to each of the tests in Experiment 3

## Discussion

In Experiment 3, infants attended to changes in both appearance and action in silent events, indicating that they can learn those isolated features even when the action fails to produce an outcome. Thus, the failure of infants' to learn the association between object appearance and whether or not those objects are functional (i.e., produce an effect when acted on) in Experiment 2 is not due to their inability to attend to and learn appearance when no effect occurs.

## General Discussion

These results contribute to our understanding of how infants represent actions in complex, multi-modal events, and add to our growing knowledge of how such representation develops in infancy. Specifically, the experiments reported here show that infants' representation of the actions performed on objects is influenced by the causal effect of those actions. Although infants fail to associate specific actions with specific outcomes (Perone & Oakes, 2006), they do learn whether or not specific actions actually produce some effect (Experiment 1). Importantly, Experiment 2 showed that infants will not learn that any distinguishing feature of an event is predictive of whether or not an outcome occurs—in that Experiment infants failed to show evidence have having learned that objects with particular appearances produce an effect when acted on. Infants do learn the isolated features of object appearance and action even when the actions do not cause salient, interesting outcomes (Experiment 3). Thus, when actions are causal infants represent those actions in different ways than when actions are not causal.

### Causal action as central to object representations

These findings are consistent with a body of work showing that actions and causes are central to how people represent objects. Neuroimaging work has revealed that the same regions of the adult human brain are activated by actions performed on objects and by the appearances of manipulable objects themselves (Martin, 2007). Theories of people's conceptions of artifact categories have argued that *function* or *causal features* are central to those categories (Ahn et al., 2000; Keil, 1989). The present results suggest that 10-month-old infants have access to such information, and their representations of objects in complex, dynamic events is influenced by whether actions performed are causal or non-causal.

Of course, because our actions are performed by a human hand, the effects we observed may reflect, in part, infants' perception of the *hand* as goal directed or as a causal agent (Leslie, 1984; Woodward, 1998). At this point, we are unable to determine the role of the hand in infants' perception of these events. Even if infants perceive the hand as central to the action, it is still the case that infants' perceptions of the events differ depending on whether the action performed by the hand results in an outcome.

Importantly, here we have examined infants' *perception* of

causality based on spatiotemporal contiguity. These results provide no evidence that infants learn, infer, or reason about a causal mechanism between the action and the outcome. Rather, we assume that the perception of the spatiotemporal contiguity between the action and the outcome highlights the action for infants because they can differentiate such causal relations from relations that are not characterized by spatiotemporal contiguity (e.g., when the cause and effect are separated in time, Oakes, 2003). Indeed, Madole and Cohen (1995) observed that 14-month-old infants were attentive to associations between the appearance of objects and how those objects functioned, even when the associations were not sensible from the perspective of physical causal mechanisms. We argue that perceiving such relations, and differentiating them from non-causal relations, provides a starting point for children's developing concepts of causal relations.

Clearly, this discussion has implications for how infants' representation and categorization of such objects develops. Theorists have long argued that function—or the kind of causal action used here—is privileged in young children's categorization. Indeed, we have observed that 6- to 7-month-old infants selectively attend to the caused action (or function) over the object appearance in the events used here (Perone, Madole, Ross-Sheehy, Carey, & Oakes, in press).

However, research on infants' perception of causal relations suggests that such perception develops considerably over the first year of life (Oakes, 2003). Although there is some evidence that infants as young as 6 or 7 months differentiate causal from non-causal launching events, this differentiation at this age is fragile and is disrupted by increasing the information-processing demands of the situation (e.g., by using more complex objects in the events, see Oakes, 2003, for a review). This developing sensitivity to causal relations would necessarily have an impact on how infants' perceive the actions in events. It is likely that older infants, whose causal perception is more robust, would interpret a broader range of action contexts as causing the outcome than would younger infants. This developmental difference would contribute to changes in how the actions are represented.

### Perceptual versus conceptual foundations of object representation

The present results might be interpreted as demonstrating that by 10 months infants have a conceptual understanding of actions, and that at this age infants' representations of objects are based on this conceptual understanding. We favor an alternative interpretation. Specifically, in our events, the differentiation between causal and non-causal actions is perceptually-based—causal actions are only causal because a sound (effect) occurs at the same time that a hand is in contact with the object. Thus, the effect is spatiotemporally contiguous with the action. We believe that results such as those presented here provide insight into how perceptual features—such as spatiotemporally defined causality—can provide the foundations for conceptual understanding that may emerge later. Results like those presented here show that

conceptual understanding may have foundations in infancy. Importantly, these results do not show that those foundations must also be conceptual in nature.

## Conclusions

In summary, the present results provide important insight into how infants represent actions, and the objects on which those actions are performed. Results reported here—in conjunction with previous findings—have implications for how infants represent artifacts. Specifically, although function may be privileged as has been argued by many theorists (Gibson, 1982; Nelson, 1974; Piaget, Grize, Szeminsk, & Bang, 1977), attention to function likely emerges with infants' developing ability to detect causal relations and differentiate them from non-causal ones. Moreover, the present results suggest that *actions* are not the most salient features in events, but that *caused actions* may have a special status—at least by 10 months—in infants representations of dynamic, multi-modal events.

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