Published in final edited form as:

Infant Behav Dev. 2011 April ; 34(2): 351–362. doi:10.1016/j.infbeh.2011.02.006.

Learning how actions function: The role of outcomes in infants' representation of events

Sammy Perone¹, Kelly L. Madole², and Lisa M. Oakes³

¹University of Iowa

²Western Kentucky University

³University of California, Davis

Abstract

Action is a fundamental component of object representations. However, little is known about how infants represent actions performed on objects. Across four experiments, we tested the hypothesis that at 10 months of age ($N = 80$) infants represent the general ability of actions to produce outcomes (sounds). Experiments 1A and 1B showed that infants encode actions and associate actions and object appearances in events in which actions produced no sound outcomes. Experiment 2 showed that infants associate the presence or absence of outcomes with actions. Experiment 3 showed, in contrast, that infants did not associate the presence or absence of outcomes with object appearances. Together, these studies suggest that infants encode the outcome potential of specific actions. We discuss the implications of these findings for our understanding of the development of action representations.

1. Introduction

Early theories of cognitive and behavioral development centered on the notion that self-generated action is a mechanism by which children acquire knowledge about the world. For Piaget (1952), object representations initially are grounded in the actions infants perform on objects (e.g., rattles are for shaking). Gibson (1988) proposed that infants' developing motor abilities provide them new opportunities to discover object properties (see also Bushnell & Boudreau, 1993). Nelson (1973) argued that infants' earliest concepts are structured around the typical actions performed on objects. A number of studies have shown that infants' exploration of objects creates developmental change in how they encode objects (e.g., Eppler, 1995; Needham, 2000; Perone, Madole, Ross-Sheehy, Carey, & Oakes, 2008). It is not surprising, then, that in the adult human brain information about actions is integrated with information about objects. For example, motor areas of cortex are active when viewing manipulable objects (e.g., Chao & Martin, 2000; Creem-Regehr & Lee, 2005), suggesting that such areas may integrate information about action with information about objects (Gerlach, Law, & Paulson, 2002). Indeed, Wolk, Coslett, and Glosser (2005) found that a patient with visual agnosia was able to use information about action to recognize objects.

© 2011 Elsevier Inc. All rights reserved

Address correspondences to Lisa M. Oakes, Center for Mind and Brain, 267 Cousteau Pl., University of California, Davis, CA 95618 (lmoakes@ucdavis.edu)..

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Actions and objects therefore appear to be inseparable components of the same representations.

Recently, there has been significant interest in how actions, and the external outcomes that actions on objects produce, are linked in infants and in adults (Elsner & Aschersleben, 2003; Elsner & Hommel, 2004; Perone & Oakes, 2006; Trauble & Pauen, 2007). In the current paper, we investigated whether infants encode the outcome producing potential of *actions* and the outcome producing potential of *objects* by examining whether they associate the presence or absence of an outcome with a particular action (Experiment 2) or a particular object (Experiment 3). Studies examining infants' representation of events--such as a woman brushing her hair or a hand manipulating an object to produce a squeaking sound--have revealed that early in infancy, actions are more salient than the physical properties of objects acted upon (Bahrick et al., 2002; Perone et al., 2008). For example, after habituation with an event in which an action is performed on an object and a sound is produced (e.g., squeezing a purple sphere produces squeaking), 6- to 7-month-old infants dishabituated to a novel *action* (e.g., rolling the same purple object) but not to a novel *object* (e.g., squeezing a pink oblong object) (Perone et al., 2008). By 10 months of age, however, infants dishabituated to events involving novel actions, objects, or sounds produced (Horst et al., 2005; Perone & Oakes, 2006). Together, these findings highlight a developmental shift from selectively encoding actions to encoding actions, the objects acted on, and the sound outcome produced when acting on an object.

The particular feature combinations that infants encode also change over development. Ten-month-old infants encode pairings between specific actions and objects (e.g., purple spheres are squeezed and yellow cubes are rolled), but not pairings between specific actions and outcomes (e.g., squeezing produces squeaking) or between specific objects and the outcomes that occur when those objects are acted on (e.g., purple spheres squeak) (Perone & Oakes, 2006). By 12 to 15 months, infants encode pairings between actions and outcomes (e.g., pulling a ring produces tones and pushing a ring makes an object light up, Elsner & Aschersleben, 2003) and between object appearance and outcomes (Baumgartner & Oakes, in press).

It is somewhat surprising that infants do not encode specific action-outcome pairings until 12 to 15 months of age because infants as young as 6 to 7 months of age can use spatiotemporal cues to encode causal relations (Oakes, 1994) like those that are often present between action and outcomes. Moreover, the salience of the actions as illustrated by the work of Bahrick and colleagues (Bahrick et al., 2002) and Perone and colleagues (Perone et al., 2008; Perone & Oakes, 2006) might lead one to predict that associations between actions and outcomes would be particularly salient. However, it is possible that infants do represent the more generic ability of actions to produce outcomes despite not associating specific outcomes with specific actions. For example, Elsner and Aschersleben (2003) found that although 12-month-old infants were more likely to produce actions on an object if they first observed those actions producing outcomes, it was not until 15 months that infants selectively reproduce *particular* actions they had observed to produce *particular* outcomes. Apparently, infants first recognized that actions on objects *could* produce outcomes before they linked specific actions with specific outcomes. Thus, we hypothesized that 10-month-old infants would link a specific action to the presence or absence of an outcome despite being unable to associate specific action-outcome pairings. Testing this hypothesis was the primary goal of this investigation.

In particular, we examined whether 10-month-old infants associated specific actions with the presence or absence of a sound outcome. We chose to focus on the link between actions and outcomes for three reasons. First, when observing actions on objects, distinct neural

populations in the adult brain represent the physical consequences of those actions; as a result, theories of action representation have defined outcomes of actions as the physical consequences of acting in the world (Hamilton & Grafton, 2006, 2007, 2008). Second, both adults (Elsner & Hommel, 2004) and non-human primates (Kohler et al., 2002) bind such outcomes to specific actions. Finally, our understanding of infants' representation of events that involve actions on objects often is based on stimulus events involving outcomes of actions such as a sound being emitted (e.g., Baldwin, Markman, & Melartin, 1993; Booth, 2006; Booth & Waxman, 2003; Elsner & Pauen, 2007; Elsner and Aschersleben, 2003; Perone & Oakes, 2006; Trauble & Pauen, 2007; Welder & Graham, 2001). Our broader theoretical understanding of action representations in human cognition, then, requires we understand the developmental origins of representing actions and such outcomes.

We conducted three experiments. First, because testing our main hypothesis required that we present infants with some actions that produce no sound outcome, in Experiments 1A and 1B we established that the absence of a sound outcome does not negatively affect infants' ability to encode actions or associate actions with object appearances. Next, we examined infants' ability to learn that one action, but not another, was associated with a sound emitting from the object acted on (Experiment 2). Finally, we addressed whether our findings were specific to infants' representation of the action by testing infants' sensitivity to the association between particular objects and the presence or absence of a sound outcome (Experiment 3).

2. Experiment 1

Experiments 1A and 1B sought to establish that infants can encode and associate actions and object appearances in the absence of sound outcomes. Infants do respond differently when actions are associated with an external event, such as a sound, versus when the same actions are performed (and the object was transformed in the same way) but no external event occurred (e.g., Booth, 2006; Elsner & Pauen, 2007; Trauble & Pauen, 2007; Wilcox & Chapa, 2004). Previous studies have shown that when actions result in a sound outcome, 10-month-old infants encoded the action, object appearance, and the connection between these two features (Horst, Oakes, & Madole, 2005; Perone & Oakes, 2006). Here, we tested whether infants encode these features in *silent* events.

2.1 Method

2.1.1 Participants—In all four experiments, infants were full-term, healthy, and typically developing with no history of vision problems. At the University of Iowa, infant names were obtained from the county birth records, and parent phone numbers were obtained from the local directory. Parents were sent informational letters and contacted by phone. At University of California, Davis, infant names were purchased from a professional list broker and parents were sent an informational letter. Parents who indicated by return post-card, phone, or e-mail an interest in participating were then contacted about this experiment. Parents were not compensated for their time, but infants received a small toy or t-shirt in appreciation for their participation.

The final sample in Experiment 1A included 16 10-month-old infants ($M = 304.94$ days, $SD = 7.11$; 8 girls), all tested at the University of Iowa; 15 infants were White (1 was Hispanic) and 1 infant was mixed race. Fifteen mothers had completed high school, 14 had some college, and 5 had graduate degrees. Additional infants were tested but excluded from the final analyses due to fussiness ($n = 2$), parental interference ($n = 1$), or failure to meet the habituation criterion (see *Procedure* section) ($n = 1$).

The final sample in Experiment 1B included 24 10-month-old infants ($M = 300.25$ days, $SD = 9.75$, 12 girls), all tested at University of California, Davis; 16 infants were White, 4 were mixed race, 2 were Hispanic, and 2 did not report race. All mothers had completed high school, 21 had some college, 7 had graduate degrees, and one did not report maternal education. Thirteen additional infants were tested but excluded from the final analyses due to fussiness ($n = 7$), experimenter error ($n = 1$), or failure to habituate ($n = 5$).

2.1.2 Stimuli—In each stimulus event, an object initially was at rest in the center of a computer screen (1 s), a hand then reached for and acted on the object (5 s), and the hand retreated, leaving the object stationary (1 s) (see Figure 1). Each object, ranging in size from 3.64° and 8.72° high by 4.00° and 6.54° (at a viewing distance of 100 cm), had wheels, was deformable upon squeezing, and had one part that could be pulled. There were four object appearances: a purple sphere, a pink tubular-shaped object with fuzzy, black balls on each end; a multicolored pyramid with a fuzzy, yellow ball on top; and a yellow cube with a pink sphere at its center. There were four actions: squeezing, rolling, inverting, or pulling a part of the object. Crossing these appearances and actions created sixteen silent events. Note that we used actions, objects, and outcomes that are typical of those infants experience daily and resemble those used by other researchers (e.g., Baldwin, et al., 1993; Welder & Graham, 2001) to ensure the generality of our findings.

2.1.3 Apparatus—Infants were tested in a dimly lit room divided by a black curtain, hanging from the ceiling to floor, with openings for a computer monitor, a small speaker to the right of the monitor, and a low-light TV camera lens below the monitor. A trained observer sat in an adjacent control room and used specialized computer software (Cohen, Atkinson, & Chaput, 2000–2002) to present the stimulus events on the computer monitor via a Macintosh computer. The stimulus events appeared on a 37 cm (w) by 27 cm (h) region of the monitor.

2.1.4 Procedure—Infants were seated on their parent's lap 100 cm in front of a computer monitor. Parents wore opaque glasses and listened to classical music via headphones to reduce bias. Between trials, a green looming circle that periodically produced a chirping sound appeared at the center of the computer monitor. When the infant fixated this attention-getting stimulus, the observer pressed a computer key which stopped the attention-getter and started the stimulus for that trial. The observer, who was unaware of the stimulus presented on each trial or whether the infant was seeing habituation or test stimuli, pressed and held a computer key while the infant looked at the stimulus. If no looking was observed in the first 10 s, the trial was stopped and repeated. Each trial continued until the infant looked away for 1 s (following at least 1 s of looking) or until 35 s had elapsed. A second observer recorded the looking times for 25% of the infants in each of the experiments reported here. Across all four experiments, the mean inter-observer correlation for duration of looking on each trial was high, $r = .99$, and the average difference between observers on each trial was low, $M = .45$ s.

2.2 Experiment 1A

Infants were habituated to a silent event involving a single object appearance and action. Infants' looking time was calculated across overlapping blocks of 3 consecutive trials: Block 1 consisted of trials 1–3, block 2 consisted of trials 2–4, and so on. Habituation continued until infants looking on any block was at least 50% of looking on the first block or a maximum of 18 trials was presented. To ensure that infants' response during test unambiguously reflected a preference for *novelty*, in each experiment only infants who satisfied this habituation criterion within the maximum number of trials were included in the

final analyses (see Oakes, 2010). Infants who completed all habituation trials without decreasing their looking to 50% of baseline were not included in the final analyses.

Immediately following habituation, we examined infants' looking time on four test trials. First, we re-presented the habituation stimulus to use as a conservative baseline measure of infants' looking to the familiar stimulus. The second and third tests evaluated whether infants encoded the object appearance and action: one test involved a novel action executed on the familiar object and the other involved the familiar action executed on a novel object. For example, an infant habituated to the hand squeezing a purple sphere might receive one test in which the hand squeezed a yellow cube (i.e., novel object appearance) and another test in which the hand rolled the purple sphere (i.e., novel action) (order of these two test trials was counterbalanced across infants). Finally, to test infants' response to novelty in general, the last test involved both a novel object and novel action. Each infant was habituated to a different silent event to ensure that our results were not specific to a particular object or action.

All infants included in the final analyses met the habituation criterion, requiring 7.88 ($SD = 3.70$) on average to reach that criterion. To test whether infants' looking remained at a low level, we used a paired t-test to compare their looking time during the last habituation block ($M = 5.03$, $SD = 2.04$) and the familiar test ($M = 5.74$, $SD = 4.44$). This comparison was not significant, $t(15) = .65$, $p = .52$, $d = .21$, indicating that infants' level of interest in the familiar item did not change from the last habituation block to the familiar item presented post-habituation. Because looking time on criterion trials can be artificially low, it can overestimate infants' level of habituation to the familiar stimulus (Bertenthal, Haith, & Campos, 1983; Dannemiller, 1984); we therefore used infants' looking on the familiar test trial as a conservative baseline for evaluating whether infants encoded the object appearances and actions.

Infants' looking during test is shown in the top portion of Figure 3. Our primary analyses compared infants' *dishabituation*, or their level of increased looking to the test relative to the familiar test item. We therefore conducted a series of paired-comparison t-tests, comparing infants' looking to the familiar test to each of the novel items. These comparisons revealed that infants dishabituated to all three events, significantly increasing their looking when object appearance was novel, $t(15) = 5.45$, $p < .0001$, $d = 1.69$, the action was novel, $t(15) = 3.88$, $p = .002$, $d = 1.55$, and both were novel, $t(15) = 5.24$, $p < .0001$, $d = 1.34$. A repeated-measures Analysis of Variance (ANOVA) comparing infants' looking to the four trials revealed a main effect of trial, $F(3, 45) = 9.64$, $p < .001$, $\eta_p^2 = .39$, confirming that infants' looking to the test trials differed. Thus, infants can encode the actions and object appearances in silent events in which no sound outcome is present as they do when a sound outcome is present (Horst et al., 2005; Perone & Oakes, 2006). Experiment 1B asked whether infants also can learn specific action-object pairings in silent events in which acting on an object does not produce a sound outcome.

2.3 Experiment 1B

We used Perone and Oakes's (2006, Experiment 5) switch design to examine infants' encoding of specific action-object pairings in these silent events. In this design, infants are habituated to two stimulus events (each is presented on half of the habituation trials) that represent pairings of two features. In the present case, the two habituation events involved an association between particular actions and particular objects (e.g., a particular infant might observe the purple object being rolled in one event and the yellow object being squeezed in the other event). Thus, in one event, action-1 is paired with object-1, and in the other event, action-2 is paired with object-2.

To ensure that each feature combination was equally familiar, we evaluated infants' habituation across blocks of 4 consecutive trials using a fixed-block criterion (i.e., block 1 consisted of trials 1–4, block 2 consisted of trials 5–8, and so on). Habituation continued until infants' looking on one block was less than 50% of their looking on the first block or a maximum of 20 trials was presented (infants who completed 20 trials without decreasing their looking by at least 50% were not included in the final analysis). There were four constraints on the order of stimulus presentation: (1) each habituation stimulus was presented twice in each block, (2) a given stimulus event occurred on no more than two consecutive trials (i.e., a particular event could not be presented on the last two trials in one block and the first in the following block), (3) the last trial of each block involved the same stimulus event, thus ensuring that the same event was presented on the last habituation trial regardless of the number of blocks required for an individual infant to meet the criterion, and (4) the familiar test event was always different than the last habituation trial. These constraints were also imposed in Experiments 2 and 3. On average, infants reached the criterion in 13.66 trials ($SD = 4.56$). Infants' looking time during the last block ($M = 7.48$, $SD = 3.57$) was not different from their looking to the familiar test ($M = 6.84$, $SD = 5.34$), $t(23) = .51$, $p = .61$, $d = .14$, two-tailed.

To test whether infants were sensitive to the association between action and object, we presented them with a “switched” test in which those features are combined in a novel way (e.g., action-1 is paired with object-2). Thus, during the switch test each of the features is equally familiar but the *combination* is novel. We also examined infants' looking time to one of the familiar habituation events, which we used as a baseline measure of infants' looking to the habituation events. The order of the familiar and switched events was counterbalanced across infants. Finally, the last test trial was a completely novel event that involved a novel object and novel action. A comparison of infants' looking time to the familiar event with their looking time to the switched event (bottom portion of Figure 3) using a two-tailed t-test was significant, $t(23) = 2.41$, $p = .02$, $d = .62$, indicating that relative to the familiar event infants increased their looking to the switched event. Infants also significantly increased their looking to the completely novel event, $t(23) = 4.04$, $p = .0005$, $d = 1.14$. This is the pattern observed by Perone and Oakes (2006, Experiment 5) when the actions produced an outcome.

The absence of a sound outcome, then, does not appear to hinder infants' ability to recognize specific action-object pairings. Recall that in previous studies infants' categorization was influenced by whether actions were associated with a similar type of outcome (auditory or visual) (Elsner & Pauen, 2007; Trauble & Pauen, 2007). Critically, the previous studies asked whether infants generalized category membership based on the presence of a critical object part that when acted on produced an outcome, whereas here we assessed infants' sensitivity to the combination of features.

Importantly, Experiments 1A and 1B demonstrate that the absence of a sound outcome does not hinder infants' ability to encode the objects or actions. Thus, we can confidently manipulate the presence and absence of a sound in Experiments 2 and 3 to test our main hypothesis.

3. Experiment 2

Experiment 2 tested our main hypothesis that 10-month-old infants will encode the outcome producing potential of specific actions. We used a switch design to test infants' ability to detect that one action was associated with a sound outcome and that another action was associated with no sound outcome.

3. 1 Method

3.1.1 Participants—Twenty 10-month-old infants ($M = 304.95$ days, $SD = 6.98$, 10 girls) participated; 16 infants were tested at the University of Iowa and 4 infants were tested at University of California, Davis. Seventeen infants were White, 1 infant was Asian, and 2 infants did not have race reported. One mother had completed eighth grade, 18 had at least some college, and 7 of those who attended college also had graduate degrees. Eleven additional infants were tested but their data excluded from the final analyses due to fussiness ($n = 3$), experimenter error ($n = 2$), or failure to meet the habituation criteria ($n = 6$).

3.1.2 Stimuli—The 16 silent events described earlier were crossed with four different (dubbed over) sound outcomes: squeaking, mooing, whistling, and clicking. For example, when the yellow cube was squeezed, rolled, inverted, or a part pulled, it could squeak, moo, whistle, and click—the sounds were contingent on the action on the object.

3.1.3 Apparatus, Design, and Procedure—The apparatus and procedure were identical to Experiment 1B, except that infants were habituated to two events that involved the same object appearance but different actions. In one event, a sound occurred when the action was performed, and in the other event a different action was performed and no sound occurred (see Figure 2A). Thus, one action produced a sound outcome and one action did not. For example, an infant might see on half of the habituation trials a purple sphere that squeaked when rolled, and on the other trials a purple sphere that was silent when squeezed. In this example, rolling, but not squeezing, has the potential to produce a sound outcome. Although it was not possible to use every combination of events, for each infant we randomly selected the combination of actions, objects, and sounds from the set of silent and sounding events (one infant might see the yellow cubes rolled and squeezed, one infant might see the purple spheres inverted and rolled, another infant might see the pink tube squeezed and a part pulled, and so on) to ensure that our findings are general.

We examined infants' looking time on four test trials. The first test was the familiar event (the sounding event for half of the infants and the silent event for the other infants). The second and third tests were the *silent switched* test, in which the action from the familiar sounding event resulted in no sound, and the *sounding switched* test, in which the action from the familiar silent event resulted in the sound from the familiar sounding event. The order of these two tests was counterbalanced across infants. For example, following the habituation events described above in which an infant saw a purple sphere that squeaked when rolled on some trials and a purple sphere that was silent when squeezed on other trials, at test this infant saw the purple sphere be silent when rolled on the silent switched test, and the purple sphere squeak when squeezed on the sounding switched test. It is important to point out that the only difference between the sounding and silent events during habituation and the sounding and silent events during the test phase was which action was paired with the sound outcome. That is, there were no novel features introduced during the switch tests. Only the combination of features was novel.

Note that during habituation, each action occurred equally frequently and actions produced sounds on half of the trials. If infants associated the presence of a sound outcome with one action and the absence of a sound outcome with another action, they will increase their looking to the switched events. If, in contrast, infants learned only the individual features (i.e., the two different actions, the fact that the sound is only heard sometimes), they will not increase their looking to the switched events. On the last test, infants saw a completely novel event (i.e., novel object, action, and sound).

3.2 Results

Only infants who met the habituation criterion were included in the final analyses; on average they habituated in 13.00 trials ($SD = 3.64$). Infants' looking time during the last block was not different from their looking to the familiar test, $t(19) = .47, p = .65, d = .14$. To determine whether infants preferred sounding events, we compared infants' looking time to sounding and silent events during the first and last block of habituation trials (see Table 1). Infants looked at sounding events longer than the silent events during the first block, $t(19) = 5.29, p < .0001, d = 1.13$, but not the last block, $t(19) = .39, p = .70, d = .12$. In addition, during the familiar test, infants presented with a sounding familiar event looked no longer than did infants presented with a silent familiar event, $t(18) = 1.47, p = .32, d = .27$. Finally, infants looked equivalently to the sounding switched and silent switched tests, $t(19) = .32, p = .75, d = .06$. Therefore, any differences observed during test were not due to infants simply looking longer to sounding events.

As seen in the top portion of Figure 4, infants looked longer at both switched events than they did to the familiar event, indicating they recognized when a previously ineffective action produced a sound and when a previously effective action was silent. Comparison of these means with two-tailed t-tests confirmed this observation: infants significantly increased their looking to both the sounding switched event, $t(19) = 2.94, p = .008, d = .64$, and the silent switched event, $t(19) = 2.18, p = .04, d = .61$. Thus, infants learned the relation between a particular action and whether or not it produced a sound. Infants also significantly increased their looking to the completely novel event, $t(19) = 5.25, p < .001, d = 1.62$.

3.3 Discussion

The results of this experiment reveal that 10-month-old infants can associate the *presence* of a sound outcome with one action and the *absence* of a sound outcome with another action, even though infants at this age apparently are not sensitive to associations between specific actions and specific sound outcomes (Perone & Oakes, 2006). Therefore, 10-month-old infants represent the general ability of *actions* to produce outcomes. Importantly, all actions performed on the objects resulted in some transformation of the object themselves (e.g., slight compression, movement across the stage, inversion), but the outcomes we manipulated were changes in the physical environment—i.e., a sound emitting. Thus, here we found that 10-month-old infants could associate actions performed on objects and whether or not there were external physical consequences of those actions present.

Although these results show that infants associated an action with the presence or absence of a sound outcome, it must be noted that this experiment does not tell us precisely what aspect of action infants associated with the presence or absence of external outcome. When infants associate the presence of a sound with squeezing a sphere, for example, they may link the outcome potential with the grasping action, the pinching of the fingers, the compression of the object, or the movement trajectory of the hand, or some combination of such features. Importantly, however, these aspects of action co-occur in space and in time and are entirely interdependent—an object cannot be transformed without the full execution of an action, and an action cannot be fully executed without transforming an object. For this reason, in studies on infants' and adults' representation of actions, these two aspects of action are typically confounded. Future work may address the question of which aspects of action are associated with the potential to produce an outcome.

We have concluded that infants learned the outcome producing potential of *actions*. It remains unknown whether this is specific to infants' representations of actions, or whether infants can learn the outcome producing potential of other aspects of the event. For example, infants also may encode the outcome potential of the *objects* that are acted on, learning for

example that purple objects make a sound when acted on but yellow objects do not. At 10 months of age, infants do not encode specific object-outcome pairings (e.g., purple spheres squeak when squeezed) (Perone & Oakes, 2006), but they may readily associate the presence or absence of sound outcomes with particular objects. In this case, we can conclude that infants are apt at learning correlations between the presence and absence of outcomes with another feature (i.e., action or objects). Alternatively, infants may only encode outcome potential of actions, indicating that we have revealed something about how infants represent actions in particular. Recall that infants' sensitivity to the different types of features in events like those used here does not develop at the same time; infants' earliest representations of events that involve actions, objects, and outcomes are centered on the actions. It is therefore possible that infants would associate the sound-producing potential with *actions* but not the appearance of *objects*. Experiment 3 addressed this possibility.

4. Experiment 3

4.1 Method

4.1.1 Participants—Twenty 10-month-old infants ($M = 302.05$ days, $SD = 8.49$; 12 girls) participated, 16 at the University of Iowa. Seventeen infants were White, 2 were Asian, and 1 was mixed race. All mothers had graduated high school, 18 had some college, and 6 had graduate degrees. We excluded 11 additional infants due to fussiness ($n = 5$), looking the maximum on the familiar test trial ($n = 1$), or failure to meet the habituation criterion ($n = 5$). Infants were recruited as described above.

4.1.2 Stimuli, Apparatus, Design, and Procedure—All aspects of this Experiment were identical to Experiment 2 except that during habituation the *object* was predictive of the presence or absence of a sound (see Figure 4B). In the *sounding* habituation event one object produced a sound when acted on (e.g., the purple sphere squeaked when rolled), and in the *silent* habituation event a different object was silent when acted on in the same way (e.g., the yellow cube was silent when rolled). In the *silent switched* test, the object from the familiar *sounding* event was silent when acted on (e.g., the purple sphere was silent when rolled), and in the *sounding switched* test the object from the familiar *silent* event produced a sound when acted on (e.g., the yellow cube squeaked when rolled).

It is important to point out that in both Experiments 2 and 3 infants were habituated to the same number of features (i.e., 2 actions, 1 appearance, and 1 sound in Experiment 2 and 1 action, 2 appearances, and 1 sound in Experiment 3). It is possible that the processing demands were different in the two experiments—for example, if it is more demanding to process to actions than to process two object appearances. Experiment 1B confirmed that in *silent* events, infants at this age can learn two object appearances and two actions. Previous results indicate that infants can also learn two object appearances and two actions in *sounding* events (Horst et al., 2005; Perone & Oakes, 2006). Thus, although we cannot definitively rule out differences in information-processing demands, previous findings make it seem unlikely that it is more difficult for infants of this age to learn two actions than to learn two object appearances, or vice versa.

4.2 Results

On average infants habituated in 15.40 trials ($SD = 4.90$), and they looked for similar durations during the last block and the familiar test, $t(19) = .02$, $p = .98$, $d = .006$. Infants looked longer to the sounding than to silent events during both the first habituation block, $t(19) = 4.34$, $p = .0004$, $d = .96$, and last habituation block, $t(19) = 4.31$, $p = .0004$, $d = .93$ (see Table 1). This apparent preference for sounding events did not persist during test. Infants who received a sounding familiar test event did not look longer at that event than did

the infants who received a silent familiar test event, $t(18) = 1.30$, $p = .23$, $d = .54$. In addition, infants' looking at sounding and silent switched tests did not differ, $t(19) = 1.45$, $p = .16$, $d = .38$. Thus, infants did not generally look longer to *sounding* test events.

In this experiment, infants did not dishabituate to the switched events, suggesting they did not learn the association between the particular object and the presence or absence of a sound (see bottom portion of Figure 3). Compared to their looking to the familiar test, infants failed to significantly increase their looking to either the sounding switched test, $t(19) = .31$, $p = .76$, $d = .33$, or the silent switched test, $t(19) = 1.10$, $p = .29$, $d = .07$. Infants did increase their looking to the completely novel test, $t(19) = 6.37$, $p < .0001$, $d = 1.97$.

4.3 Discussion

These results provide a striking contrast to those of Experiment 2. In Experiment 3, infants did not respond when a previously silent object produced a sound or a previously sounding object was silent when acted on. This failure might indicate that infants do not associate the appearance of specific objects with the presence or absence of sound outcomes. That is, although Experiment 2 suggests they can learn that some actions (e.g., squeezing) produce sounds and other actions (e.g., rolling) do not, they do not learn that some objects (e.g., purple round objects) make a sound when they are acted on and other objects (e.g., yellow cubes) do not make a sound when acted on. Alternatively, infants may have failed to learn the association in this event because they had inconsistent information about the sound-producing potential of the *action*. On half of the trials, the action produced a sound (when it was performed on one object) and on the other trials, the action failed to produce a sound (when it was performed on a different object). That is, the associations between action and outcome may be so compelling that infants only can learn those associations, if they are available, and they do not detect other associations between the presence or absence of an outcome and other features. What is clear from Experiment 3 is that infants did not associate the sound outcome with the appearance of the object. Together, Experiments 2 and 3 suggests that infants' sensitivity to relations between actions and outcomes and objects and outcomes is different at 10 months of age.

5. General Discussion

Ten-month-old infants were sensitive to the relation between actions and the presence of a sound outcome but not the relation between the object being acted on and the presence of a sound outcome. Thus, for infants, outcomes appear to be differentially linked to actions and objects. Below, we discuss implications of these findings for our broader theoretical understanding of how actions are represented in human cognition. We also discuss implications for our understanding of infants' emerging conception of object function.

5.1 Action Representations In Human Cognition

There are two influential theories of how actions are represented in human cognition. First, inspired by neurophysiological data showing that distinct neural populations are involved in representing different aspects of events, Hamilton and Grafton (2007, 2008) proposed that kinematic aspects of actions, goals to act on an object, and external outcomes are represented independently and hierarchically. For example, representing a light switch being flipped involves encoding the kinematics required to execute the goal of flipping the switch to achieve the outcome to bring light. Hommel and colleagues (Elsner & Hommel, 2004; Fagioli, Ferlazzo, & Hommel, 2007) proposed a second model. Their *common coding hypothesis* posits that associative learning mechanisms allow sensory events that reliably co-occur with actions to become integrated with those actions. Indeed, adults bind external outcomes with specific actions (e.g., Elsner & Hommel, 2004), and neurophysiological

recordings in nonhuman primates revealed cortical activity involved in the execution of an action was present when observing the sound outcomes associated with that action (Kohler et al., 2002).

Infants' representation of actions is best understood by considering these two frameworks together. Consistent with the hierarchical model, by 7 months infants represent actions, objects, and outcomes independently (Baumgartner & Oakes, in press; Perone et al., 2008). Consistent with the common coding hypothesis, between 10 and 15 months infants develop the ability to combine or integrate such features (Baumgartner & Oakes, in press; Elsner & Aschersleben, 2003; Perone & Oakes, 2006). Together, these findings support the general developmental model that infants first represent individual features and later represent the connections between those features (Cohen, 1988; Poulin-Dubois & Rakison, 2002; Rakison, 2004; Younger & Cohen, 1986).

The present findings add new insight into the development of feature integration in such events. Perone and Oakes (2006) reported that 10-month-old infants associated actions with particular objects, but did not associate actions with particular outcomes. The present results show that this failure does not represent a general inability to associate actions and outcomes; 10-month-old infants *can* associate actions with the presence or absence of an outcome. Thus, at this age, infants can learn the *specific* relations between particular actions and particular objects, but they represent the *general* property of actions to produce *an* outcome.

Why would infants represent abstract relations between actions and outcomes and yet encode specific relations between actions and objects? We can only speculate at this point, but there are at least two possibilities. One, infants may simply integrate actions and objects first, and before 10 months infants may represent abstract relations between them. Baumgartner and Oakes (in press) observed that 8-month-old infants are insensitive to specific relations between actions and objects in these events, but it is possible that at this age they represent the abstraction that some objects are acted on and other objects are not.

A more intriguing possibility is that the difference in infants' sensitivity to these relations reflects differences in the regularities in the infants' experience between actions and objects and actions and outcomes. Elsner and Hommel (2004) argued that actions are only integrated with other features of events if the correlations between those features are strong. The different relations infants form may reflect differences in the strength of the correlations they experience in their environment. Specifically, in the infants' experience, correlations between actions producing *an* outcome may be stronger than the correlation between actions and *specific* outcomes. Performing a particular action on an object may have multiple consequences (a toy may play a different sound each time a button is pressed) and the same action may result in different outcomes on different objects (when shaken, some objects may rattle and others may ring). As adults, we know that the specific outcome produced is constrained by the physical features of objects, but those physical constraints often are not observable—e.g., shaking an object with bells *inside* will cause ringing; shaking an object with beads *inside* will cause rattling. Thus, in the infants' experience, the fact that shaking produces a sound is regular and predictable; the particular sound shaking produces is unpredictable and arbitrary.

There may be a stronger correlation between what actions are performed on objects and the particular physical characteristics (e.g., shape, texture, presence of parts) of the objects. We squeeze spheres, roll objects with wheels, shake objects with handles, push buttons, and so on. As a result, infants may be more sensitive to these specific relations. The point is that the particular kinds of associations infants learn in the laboratory may reflect their learning

accumulated over a longer timeframe outside the laboratory. An important question for future research will be to explore infants' out-of-laboratory experience with actions, objects, and outcomes to gain insight into why they are biased to encode the relations they do in events like those used here.

5.2 Why did infants learn the outcome producing potential of actions but not objects?

The present data suggest that infants learn the general property of “produces a sound outcome” of actions but not objects. It is possible that this difference in learning reflects differences in the level of temporal contiguity between action and the outcome and between the outcome and the object appearance is different. Outcomes are often temporally contiguous with the execution of the action. In our events, outcomes occurred when the hand made contact with and acted on the object. Outcomes are not temporally contiguous with objects. In our events, the appearance of the object (e.g., its color, overall shape, presence of features) is present for seconds before and after it is acted on and a sound outcome is heard. Because temporal contiguity is necessary to integrate outcomes and actions (Elsner & Hommel, 2004), differences in the associations infants form may reflect these differences in temporal contiguity.

These temporal contiguity differences also may have induced infants to perceive the *actions*, but not the *objects*, as causal agents. By 7 months of age, infants use temporal contiguity to perceive causality in events (Oakes, 1994; Leslie, 1984), and infants have been shown to associate dynamic cues, such as the dynamic movement of the parts (in this case the fingers) with causal agency (Rakison, 2005). Moreover, infants have a general bias to encode the *agent* of a causal event, even failing to encode the features of the recipient (see Cohen & Oakes, 1993). Thus, infants may have been biased to perceive the connection between the action and the outcome.

Infants also may have learned the outcome producing potential of actions but not objects because of *Action-effects* (Biro & Leslie, 2007; Elsner & Hommel, 2004; Prinz, 1997). That is, representations of actions and their outcomes may be inextricably linked (Prinz, 1997); representations of objects and outcomes may not be linked in this way. Thus, associating actions with their potential to produce outcomes may reflect selective attention to the action-outcome relations due to the very nature of how actions are represented. Indeed, action-effects can have a powerful influence on how infants represent the goal of a human action (Biro & Leslie, 2007) and in how they reproduce actions they see performed (Elsner, 2007). Importantly, these possibilities are not mutually exclusive. The differences we observed between Experiments 2 and 3 may have resulted from infants' bias to attend to the perceived cause of an outcome *and* to their perception of action-effects. Future research may determine the relative contribution of each of these mechanisms on infants' representations.

5.3 Implications For Our Understanding of Infants' Conceptions of Object Function

Finally, results like those reported here are important for our understanding of infants' developing conceptions of object function. In part, this is because when studying infants' understanding and representation of object function, the “functional” properties of objects are often demonstrated using the kinds of actions and outcomes we used here. For example, function is conceived (by the researchers) as squeaking when squeezed (Horst et al., 2005; Perone & Oakes, 2006; Welder & Graham, 2001), hanging and swinging from a hook (Booth & Waxman, 2002), or producing a sound when a part is inserted in an opening (Trauble & Pauen, 2007). Moreover, the external outcome is critical for how function is considered in these studies; experimenters give functional demonstrations by acting on objects and an outcome is produced, and give non-functional demonstrations in which the identical actions performed without producing the external outcome (Trauble & Pauen,

2007; Welder & Graham, 2001; Wilcox & Chapa, 2004). In these studies it is assumed that infants will link the action and the outcome, and the fact that infants perceive or respond differently when there is an external outcome results from their perception (at some level) of this link. Thus, investigations like the one presented here, in which we systematically examined how infants represent the relations between the actions and outcomes, are critically important for our understanding of infants' conceptions of function as they have been examined in the literature.

Results like those reported here are also important because function typically is considered a unified object property that is effortlessly perceived by infants (Graham & Diesendruck, 2010; Ware & Booth, 2010; see Samuelson & Perone, 2010 for a discussion). However, our results are more consistent with recent views that function is a property that emerges from the interaction of multiple features of the object, the observer, and the context (e.g., Barsalou, Sloman, & Chaigneau, 2005; Oakes & Madole, 2008). Infants do not perceive the elements of function as part of a unified or integrated whole. Instead, over development infants begin to encode and recognize individual features and different aspects of the relations among them. Early in development, infants encode actions but not the objects being acted on (Bahrick et al., 2002; Perone et al., 2008). By 10 months of age, infants learn specific action-object pairings (Perone & Oakes, 2006). Around the end of the first year, infants learn specific action-outcome and object-outcome pairings (Baumgartner & Oakes, in press; Elsner & Aschersleben, 2003). As described above, there may be many potential experiential contributions to these developmental changes. However, changes in basic cognitive processes may also contribute. The abrupt onset and dynamic nature of actions, for example, might recruit young infants' limited attentional and processing resources (see Robinson & Sloutsky, 2004; Shaddy & Colombo, 2004). With age, infants' ability to process and remember multi-element displays increases (Ross-Sheehy, Oakes, & Luck, 2003), which may enable them to encode relations among multiple features present in an event. At present, it is unclear how changes in basic cognitive processes influence how infants learn about function. However, it is clear that how infants come to think about how objects *function* is a developmental process by which they learn how actions, objects, and outcomes are related to each other. The present findings provide insight into how infants might begin to link relations among actions and outcomes. Thus, we gain deeper insight into how infants' conceptions of function emerge over time by examining the development of their representation of actions.

5.4 Conclusion

In summary, these results provide an important step in our understanding of how infants represent actions on objects. Actions are an important component of how adults represent objects, embody a host of statistical regularities that infants are sensitive to, and are the centerpiece of events that reveal an object's function. We found that at 10 months infants associate the presence of outcomes with actions but not objects that are acted on, despite other findings showing that they are unable to associate specific action-outcome pairings. Thus, infants represent the general ability of actions to produce outcomes, a developmental achievement that coincides with specific action-object representations but precedes more specific action-outcome representations.

Acknowledgments

This work was made possible by NIH grant HD49840 and by NSF grant BCS 0921634, both awarded to LMO. We thank Shaena Stille, Lisa Christoffer and undergraduates in the University of Iowa and University of California, Davis Infant Cognition Laboratories. Some of these data were presented at the Cognitive Science Society meeting, July 2008, Washington DC.

References

- Bahrack 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]
- Baldwin DA, Markman EM, Melartin RL. Infants' ability to draw inferences about nonobvious properties: Evidence from exploratory play. *Child Development*. 1993; 64:711–728. [PubMed: 8339691]
- Baumgartner HA, Oakes L. Infants' developing sensitivity to object function: Attention to features and feature correlations. *Journal of Cognition and Development*. in press.
- Bertenthal BI, Haith MM, Campos JJ. The partial-lag design: A method for controlling spontaneous regression in the infant-control habituation paradigm. *Infant Behavior & Development*. 1983; 6:331–338.
- Barsalou, L.; Sloman, S.; Chaigneau, S. The HIPE theory of function. In: Carlson, L.; Van Der Zee, E., editors. *Functional features in language and space: Insights from perception, categorization, and development*. Oxford University Press; New York: 2005. p. 131-148.
- Biro S, Leslie A. Infants' perception of goal-directed actions. Development through cues-based bootstrapping. *Developmental Science*. 2007; 10:379–398. [PubMed: 17444978]
- Booth AE. Object function and categorization in infancy: Two mechanisms of facilitation. *Infancy*. 2006; 10:145–169.
- Booth AE, Waxman S. Object names and object functions serve as cues to categories for infants. *Developmental Psychology*. 2002; 38:948–957. [PubMed: 12428706]
- Chao LL, Martin A. Representation of manipulable, man-made objects in the dorsal stream. *NeuroImage*. 2000; 12:478–484. [PubMed: 10988041]
- Cohen, LB. An information processing approach to infant cognitive development. In: Weiskrantz, L., editor. *Thought without language*. Clarendon Press; New York: 1988. p. 211-228.
- Cohen, LB.; Atkinson, DJ.; Chaput, HH. *Habit 2000: A new program for obtaining and organizing data in infant perception and cognition studies (version 1.0)* [computer software]. The University of Texas; Austin, TX: 2000–2002.
- Dannemiller JL. Infant habituation criteria: I. A monte carlo study of the 50% decrement criterion. *Infant Behavior & Development*. 1984; 7:147–166.
- Creem-Regehr SH, Lee JN. Neural representations of graspable objects: Are tools special? *Cognitive Brain Research*. 2005; 22:457–469. [PubMed: 15722215]
- Elsner B, Aschersleben G. Do I get what you get? Learning about the effects of self-performed and observed actions in infancy. *Consciousness and Cognition*. 2003; 12:732–751. [PubMed: 14656514]
- Elsner B, Hommel B. Contiguity and contingency in action-effect learning. *Psychological Research*. 2004; 68:138–154. [PubMed: 14685854]
- Elsner B, Pauen S. Social learning of artefact function in 12- and 15-month-olds. *European Journal of Developmental Psychology*. 2007; 4:80–99.
- Eppler MA. Development of manipulatory skills and the deployment of attention. *Infant Behavior and Development*. 1995; 18:391–405.
- Fagioli S, Ferlazzo F, Hommel B. Controlling attention through action: Observing actions primes action-related stimulus dimensions. *Neuropsychologia*. 2007; 45:3351–3355. [PubMed: 17688892]
- Gerlach C, Law I, Paulson OB. When actions turn 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; 39:1–31.
- Graham SA, Diesendruck G. Fifteen-month-old infants attend to shape over other perceptual properties in an induction task. *Cognitive Development*. 2010; 25:111–123.
- Hamilton AF, de C, Grafton ST. Goal representation in human anterior intraparietal sulcus. *The Journal of Neuroscience*. 2006; 26:1133–1137.

- Hamilton, AF.; de, C.; Grafton, ST. The motor hierarchy: From kinematics to goals and intentions. In: Rosetti, Y.; Kawato, M.; Haggard, P., editors. *Sensorimotor Foundations of Cognition: Attention and Performance*. Vol. XXII. Oxford University Press; New York: 2007. p. 381-408.
- Hamilton AF, de C, Grafton ST. Action outcomes are represented in human inferior frontoparietal cortex. *Cerebral Cortex*. 2008; 18:1160–1168. [PubMed: 17728264]
- 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]
- Kemler Nelson DG. Principle-based inferences in young children's categorization: Revisiting the impact of function on the naming of artifacts. *Cognitive Development*. 1995; 10:347–380.
- Kemler Nelson DG. Attention to functional properties in toddlers' naming and problem-solving. *Cognitive Development*. 1999; 14:77–100.
- Kemler Nelson DG, Russell R, Duke N, Jones K. Two-year-olds will name artifacts by their functions. *Child Development*. 2000; 71:1271–1288. [PubMed: 11108096]
- Kohler E, Keysers C, Umiltà MA, Fogassi L, Gallese V, Rizzolatti G. Hearing sounds, understanding actions: Action representation in mirror neurons. *Science*. 2002; 297:246–248.
- Landau B, Smith LB, Jones S. Object shape, object function, and object name. *Journal of Memory and Language*. 1998; 38:1–27.
- Madole KL, Cohen LB. The role of object parts in infants' attention to form-function correlations. *Developmental Psychology*. 1995; 31:637–648.
- Needham A. Improvements in object exploration may facilitate the development of object segregation in infancy. *Journal of Cognition and Development*. 2000; 1:131–156.
- Nelson K. Some evidence for the cognitive primacy of categorization and its functional basis. *Merrill-Palmer Quarterly*. 1973; 19:21–39.
- Oakes LM. Using habituation of looking time to assess mental processes in infancy. *Journal of Cognition and Development*. 2010; 11:255–268. [PubMed: 20730029]
- Oakes LM. Development of infants' use of continuity cues in their perception of causality. *Developmental Psychology*. 1994; 30:869–879.
- 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]
- Perone S, Madole KL, Ross-Sheehy S, Carey M, Oakes LM. The relation between infants' activity with objects and attention to object appearance. *Developmental Psychology*. 44:1242–1248. in press. [PubMed: 18793058]
- Piaget, J. *The Origins of Intelligence in Children*. International Universities Press, Inc.; New York, NY: 1952.
- Prinz W. Perception and action planning. *European Journal of Cognitive Psychology*. 2007; 9:129–154.
- Rakison DH. Infants' sensitivity to correlations between static and dynamic features in a category context. *Journal of Experimental Psychology*. 2004; 89:1–30.
- Rakison, DH. Parts, motion, and the development of the animate-inanimate distinction. In: Rakison, DH.; Oakes, LM., editors. *Category and concept development: Making sense of the blooming, bussing confusion*. Oxford University Press; New York: 2003. p. 159-192.
- Rakison DH. A secret agent? How infants learn about the identity of objects in a causal scene. *Journal of Experimental Child Psychology*. 2005; 91:271–296. [PubMed: 15869760]
- Rakison DH, Poulin-Dubois D. You go this way and I'll go that way: Developmental changes in infants' detection of correlations among static and dynamic features in motion events. *Child Development*. 2002; 73:682–689. [PubMed: 12038545]
- Robinson CW, Sloutsky VM. Auditory dominance and its change in the course of development. *Child Development*. 2004; 75:1387–1401. [PubMed: 15369521]
- Ross-Sheehy S, Oakes LM, Luck SJ. The development of visual short-term memory capacity in infants. *Child Development*. 2003; 74:1807–1822. [PubMed: 14669897]
- Shaddy D, Colombo J. Developmental changes in infant attention to dynamic and static stimuli. *Infancy*. 2004; 5:355–365.

- Samuelson LK, Perone S. Rethinking conceptually-based inference: Grounding representation in task and behavioral dynamics. Commentary on “Fifteen-month-olds attend to shape over other perceptual properties in an induction task,” by S. Graham and G. Diesendruck, and “Form follows function: Learning about function helps children learn about shape,” by E. Ware and A. Booth. *Cognitive Development*. 2010; 25:138–148. [PubMed: 20526449]
- Trauble B, Pauen S. The role of functional information for infant categorization. *Cognition*. 2007; 105:362–379. [PubMed: 17129581]
- Ware EA, Booth AE. Form follows function: Learning about function helps children learn about shape. *Cognitive Development*. 2010; 25
- Welder AN, Graham SA. The influence of shape similarity and shared labels on infants' inductive inferences about non-obvious properties. *Child Development*. 2001; 72:1653–1673. [PubMed: 11768138]
- Wilcox T, Chapa C. Priming infants to attend to color and pattern information in an individuation task. *Cognition*. 2004; 90:265–302. [PubMed: 14667698]
- 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]
- Younger BA, Cohen LB. Developmental change in infants' perception of correlations among attributes. *Child Development*. 1986; 57:803–815. [PubMed: 3720405]

Figure 1. Shows the four object appearances (pink tube, yellow cube, purple sphere, and multicolored pyramid). Also shows an example of each action (pulling a part, inverting whole object, rolling object, squeezing object). Each action could be performed on each object.

Figure 2.

Examples of the stimulus events used in all experiments (in Experiments 1A and 1B, the events were silent). The habituation and test phase refer to the experimental design of Experiment 2 (A) and Experiment 3 (B).

Figure 3. Looking times (in seconds) for each test in (A) Experiment 1A and (B) Experiment 1B. Error bars represent 95% confidence intervals. Significant comparisons are indicated by asterisks: ** $p < .01$, *** $p < .0001$.

Figure 4. Looking times (in seconds) for each test in (A) Experiment 2 and (B) Experiment 3. Error bars represent 95% confidence intervals. Significant comparisons are indicated by asterisks: * $p < .05$, ** $p < .01$, *** $p < .001$, **** $p < .0001$.

Table 1

Mean looking time in s (SD in parentheses) during the first and second blocks of trials during habituation in Experiments 2 and 3.

	Block 1		Block 2	
	Sounding	Silent	Sounding	Silent
Experiment 2	25.67 (7.94)	15.66 (9.26)	6.84 (4.32)	6.39 (2.74)
Experiment 3	22.72 (9.12)	14.24 (8.59)	8.65 (6.05)	4.39 (2.34)