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Visual Experience Enhances Infants' Use of Task-Relevant Information in an Action Task

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Four experiments examined whether infants' use of task-relevant information in an action task could be facilitated by visual experience in the laboratory. Twelve- but not 9-month-old infants spontaneously used height information and chose an appropriate (taller) cover in search of a hidden tall toy. After watching examples of covering events in a teaching session, 9-month-old infants succeeded in an action task that involved the same event category; learning was not generalized to events from a different category. The present results demonstrate that learning through visual experience can be transferred to infants' subsequent actions. These findings shed light on the link between perception and action in infancy.

Keywords: infancy, perception and action, experience, physical variables, choice tasks

A fundamental aspect of human cognition is to select and use information most relevant to the task at hand. Recent research suggests that infants possess limited ability to keep track of task-relevant information about object features in dynamic events (e.g., Baillargeon, 2002; Needham, 1998; Wilcox, 1999). For example, infants younger than 12 months of age typically fail to use height information when they watch an event in which a rigid cover is lowered over an object, resulting in their failure to detect a change to the object's height (Wang & Baillargeon, 2006) and failure to detect a violation when a tall object becomes fully hidden under a short cover (Wang, Baillargeon, & Paterson, 2005).

Two related accounts help explain the development in infants' ability to use task-relevant information in physical events. First, an event-categorization account suggests that infants attend to information about spatial relations between objects (e.g., whether one object is behind, inside, or under another object) and use it to categorize an event. Recent evidence for this account includes several examples of event categories formed in infancy, such as occlusion, containment, covering, and support events (e.g., Casasola, Cohen, & Chiarello, 2003; Hespos & Baillargeon, 2001; McDonough, Choi, & Mandler, 2003; see Baillargeon & Wang, 2002, for a review). Second, a variable-identification account suggests that when learning about an event category, infants notice physical variables that mediate the outcomes of events from the category. The age at which infants notice a variable as relevant for an event category depends by and large on the experience infants have with the category (see Baillargeon, 2004, for related discussion). For example, with experience, infants may begin to notice that the height of a cover relative to that of an object determines whether the cover will fully or only partly hide the object when lowered over it (Wang & Baillargeon, in press). Once a variable is identified, infants routinely use information about the variable for all events they encounter from the category. This account predicts that a variable, once learned, should be generalized across all events from the same category, even when the events involve different stimuli and require different response modalities. The present research tests this prediction, using a laboratory-training approach.

Experience, without a doubt, plays an important role in early development. Past research has shown that motor experience affects the development of distance perception, intentional reaching, and the ability to search for a hidden object (e.g., Campos et al., 2000; Kellman & Arterberry, 1998; Smith, Thelen, Titzer, & McLin, 1999; Thelen et al., 1993). More recently, investigators have reported effects of experience at home or in the laboratory on infants' perception and action (e.g., Amso & Johnson, 2006; Baillargeon, Fisher, & DeJong, 2000; Needham, 2000; Needham, Barrett, & Peterman, 2002; Sommerville, Woodward, & Needham, 2005; Wang & Baillargeon, 2005, in press; Wilcox & Chapa, 2004). First, infants' experience acting upon objects enhances their ability to segregate objects (Needham, 2000) and to interpret goal-directed behavior in looking-time tasks (Sommerville et al., 2005); it also elevates infants' level of object exploration (Needham et al., 2002). Second, infants' experience observing an event that highlights an object feature enhances their ability to detect violations involving the same feature when they watch a subsequent event (Wang & Baillargeon, 2005; Wilcox & Chapa, 2004). Finally, infants' experience observing exemplars from an event category enhances their ability to detect violations when they watch other events from the same category (Baillargeon et al., 2000; Wang & Baillargeon, in press). Investigations of experiential effects on infant cognition help specify their underlying mech-

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anisms. Although much evidence for experiential effects in infancy has been obtained, less research is focused on whether the effects are transferred across perception and action modalities. The present research seeks to fill this gap.

The relation between perception and action has been a source of debate (e.g., Bertenthal, 1996; Bremner, 2000; Kellman & Arterberry, 1998; Willatts, 1997): Investigators have disagreed on whether perception and action operate through the same representational system in early childhood. This debate is derived primarily from the dissociation of young children's performance in looking and search tasks: Whereas looking responses often reveal early success in tracking a hidden object (e.g., Baillargeon, Spelke, & Wasserman, 1985; Spelke, Breinlinger, Macomber, & Jacobson, 1992), search responses tend to reveal persistent failure to find a hidden object (e.g., Hood, Carey, & Prasada, 2000; Mash, Novak, Berthier, & Keen, 2006) or reveal perseverative errors when an object's hidden location is visibly changed (the A-not-B error; e.g., Diamond, 1985; Munakata, 1997, 1998; Piaget, 1954; Smith et al., 1999). Investigations that sought to explain the looking–search dissociation have focused on frontal cortex maturation and inhibitory control (Diamond, 1991), representation strength (Munakata, 2001), motor history formed during a task (Thelen, Schöner, Scheier, & Smith, 2001), or differing demands related to looking and search tasks (e.g., Baillargeon, Graber, DeVos, & Black, 1990; Keen & Berthier, 2004).

Several approaches have proved helpful to investigating perception–action relations. One such approach compares infants' performance in looking and search tasks that test the same physical intuition; converging evidence across these tasks implies that the same representational system underlies perception and action (e.g., Hespos & Baillargeon, 2006). Another approach examines whether learning through one modality can be transferred to the other modality. Indeed, there already exists evidence for *action–perception* transfer. For example, infants' locomotor experience facilitates perception of spatial information (Campos et al., 2000), and their manual experience enhances perception of others' behavior (Sommerville et al., 2005). The present research focuses on *perception–action* transfer and investigates the issue of perception–action relations by (a) comparing infants' performance in a new action task with that in previous looking-time experiments and (2) testing whether infants transfer what they learn through visual experience to their subsequent performance in the action task.

In Experiment 1, we examined 12-month-old infants' spontaneous use of height information in covering events with a choice task and tested whether this action task would yield converging evidence with previous looking-time reports (Wang & Baillargeon, 2006; Wang et al., 2005). Experiments 2 and 3 investigated perception–action transfer. We tested 9-month-old infants' performance in the same task and examined whether they could be "taught" through watching examples of covering events to use height information in the task that involved the same event category. In Experiment 4, we asked whether infants would generalize this learning to a different event category.

Experiment 1

A choice task was designed to assess whether infants attend to and use height information in covering events. A tall toy was hidden, and infants were forced to choose one of two covers in search of the hidden toy. One cover was tall enough to fully hide the toy, and the other was too short. Infants' choice of the tall cover was taken to indicate that they attended to and used height information in this task. Several characteristics of our task made it simple for infants. First, the spatial elements present in the task required minimal integration; stimuli were placed side by side and plainly visible to infants. Second, infants were given two perceptually distinct choices; the two covers were markedly different in height. Third, infants' success required only the use of height information, rather than making a precise prediction of an outcome.

Twelve-month-old infants were tested in Experiment 1. Recent research indicates that infants' action performance often matches their looking responses when the demands of action tasks are low (e.g., Ahmed & Ruffman, 1998; Berthier et al., 2001; Hespos & Baillargeon, 2006). Previous looking-time experiments show that infants begin to use height information in covering events at about 12 months (Wang & Baillargeon, 2006; Wang et al., 2005); thus, we predicted that the 12-month-olds should succeed in the choice task. Additional 12-month-olds were tested in a control condition to assess whether they possess an intrinsic bias for tall over short covers. In this condition, a short toy that could be fully hidden under either cover was used to replace the tall toy.

Method

Participants. Participants were 32 healthy full-term infants, 15 boys and 17 girls, ranging in age from 11 months 24 days to 13 months 18 days; they were primarily Caucasian from middle-class backgrounds. Half of the infants were randomly assigned to the tall-toy condition (mean age = 12 months 15 days), and half were randomly assigned to the short-toy condition (mean age = 12 months 16 days). Four additional infants were tested but excluded from the analyses for not producing any responses (2), for choosing both covers (1), or for parental interference (1). Participants were recruited from birth announcements and local hospitals. Parents received travel reimbursement but were not otherwise compensated for participation.

Apparatus. A table was used with markings (two lines of squares; see Figure 1a) on its surface. The markings served as a visual guide to ensure that stimuli were equidistant from the infants when their choice was made (see *Procedure*). In the tall-toy condition, a toy bottle and two cylindrical covers were used (see Figure 1b). The toy was 3.3 cm in diameter, 10.8 cm high, and filled with yellow liquid. The covers were 5.5 cm in diameter and decorated with blue contact paper; one was 11.5 cm high and the other 4.5 cm high. In the short-toy condition, the same covers were used along with a toy rhinoceros (4 cm high). A rectangular screen was used in both conditions for hiding the stimuli during the task (see below); it was 40 cm wide, 32 cm high, and decorated with pastel contact paper.

Procedure. During the experiment, the infant sat on the parent's lap in a cut-out area against the front edge of the table; an experimenter sat across from the infant. The parent was instructed to remain silent and neutral. Each infant received a single trial consisting of a showing and a test phase; the order and location of the cover in use were counterbalanced across infants.

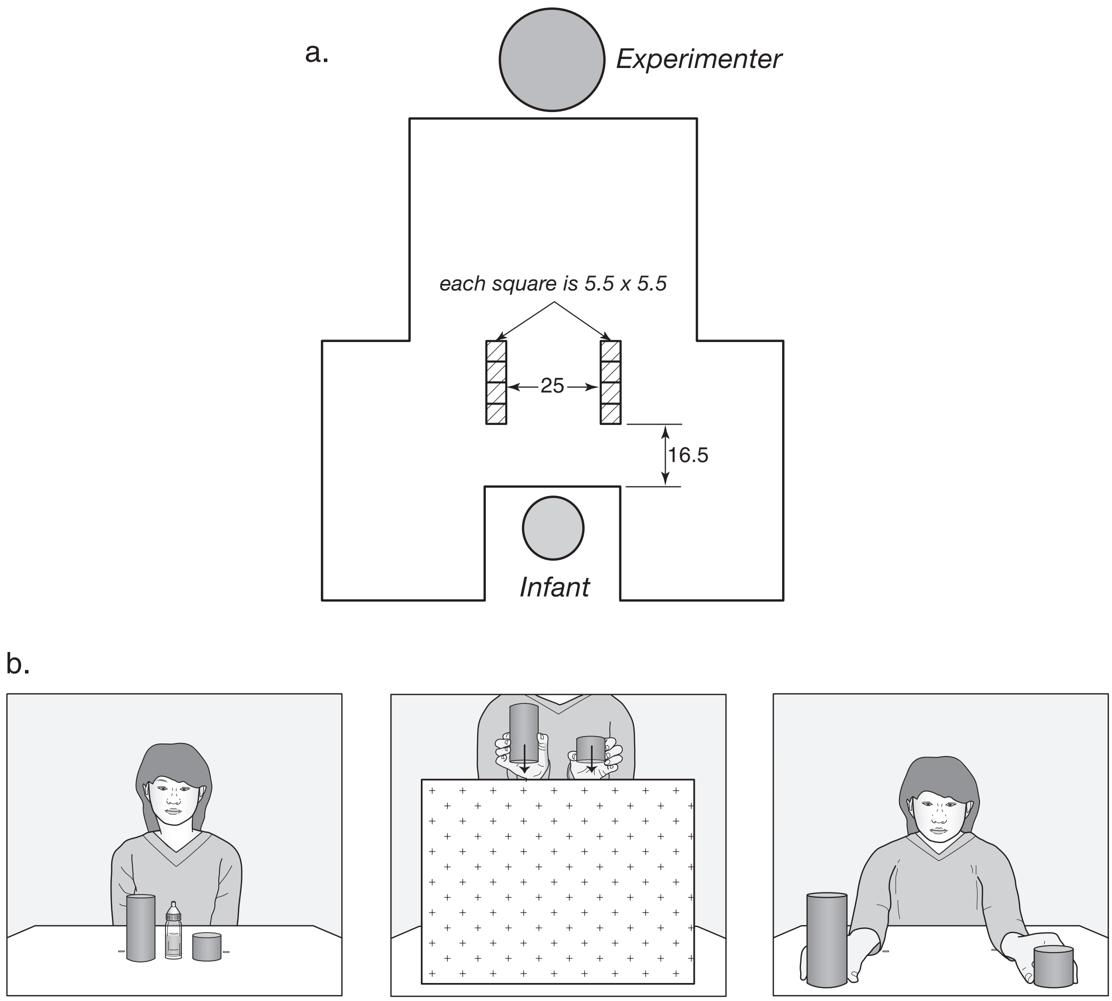

Figure 1. Schematic drawings of a bird's eye view of the table (a) and the test phase of the choice task (b). Numbers represent the dimensions in centimeters.

At the beginning of the *showing* phase, the screen was placed on the table, 38 cm from the infant; the covers and toy stood behind the screen so that attention could easily be directed to whichever object was being shown. To start, the experimenter retrieved a cover from behind the screen, tapped the side of the cover, showed its closed top and hollow interior, and then gave it to the infant. After 10 s (determined by a timer), the experimenter retrieved the cover from the infant and placed it behind the screen, and then repeated the same showing sequence with the other cover. Next, the infant was given the toy for 15 s. The experimenter then removed the screen and set it on the floor, revealing the two covers that stood 6.5 cm apart and 53.5 cm from the infant. Finally, the toy was placed in the center between the two covers.

At the start of the *test* phase, the experimenter tapped the top of the toy to draw the infant's attention, lowered one cover to hide the top centimeter of the toy, and then repeated this sequence with the other cover. Next, the screen was placed at its starting position on the table, fully hiding all stimuli. The covers were lifted above and then lowered behind the screen. After the toy was hidden, the experimenter placed the screen on the floor and slid the two covers simultaneously toward the infant, using the markings on the table to ensure that the covers were equidistant from the infant.[1] The experimenter then released the covers and looked at the timer on the wall behind the infant. If no response was produced within 30 s, the experimenter slid both covers 5.5 cm closer to the infant and waited for another 30 s. The trial ended after the second attempt; participants who failed to produce any responses were replaced.

The infants' responses during the 30-s interval (starting from the experimenter's releasing the covers) were coded frame by frame by two independent coders. The coders did not see the height of the

[1] The covers were placed outside the infant's immediate reach to encourage or force the infant to choose only one cover. Thus, the distance between the covers and infant varied across participants, depending on the infant's arm length. The experimenter determined the distance while the infant was seated with her or his hands placed on the table near the markings. In this and the following experiments, the cover–infant distance ranged from 16.5 to 33 cm.