

# Children and Adults Learn Actions for Objects More Readily Than Labels

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Researchers tend to investigate word learning and action learning as separate and independent developments. Recently, however, a growing body of evidence suggests that underlying both labels and actions are parallel processes tightly coordinated with perceptual and motor functions. The present research addresses the nature of this developmental relation in the context of learning about objects. In three studies, children and adults were trained to map novel names and arbitrary actions to a set of unfamiliar objects. Receptive and productive knowledge were assessed. Two main findings emerged. First, participants of all ages learned actions more readily than labels. Second, the relationship between understanding and producing varied as a function of condition. The results suggest that actions are more accessible in memory than labels. Findings are interpreted within an embodied cognition framework according to which sensorimotor states form the basis of object concepts throughout development.

Among the many tasks that young children must master is learning about the nature of artifacts in their everyday lives, in particular, what they are called, what they are used for, and how they are classified. Gibson (1979) argued that perceptual learning is key to understanding these fundamental processes. Babies learn about the properties of objects first through visual exploration and later, as a result of increased motor control, through such activities as grasping, mouthing, squeezing, banging, and dropping. Exploratory activity of this kind is important for discovering not only the physical properties of things, for example, the texture, size, and shape of objects, but also their natural affordances (Gibson & Gibson, 1955). Thus, a child learns through direct experience that straws afford bending, peeking, and poking. In the human world of artifacts, however, many of the everyday objects that children encounter also have nonobvious *intentional* affordances. Children typically learn that straws are for drinking, not through self-exploration but rather by observing the actions of others (Mareschal & Johnson, 2003). Indeed, figuring out the appropriate action for which an object is designed is a task that continues throughout adulthood. Corkscrews, olive pitters, and turkey basters all require knowledge of the object's intended

function. Yet unlike Gibson's 'natural' affordances, the intentional affordances of artifacts are often less perceptible even though they may be related to the object structure. As such, they must be transmitted culturally instead of learned through self-exploration (Tomasello, 1999; see also the literature on the design stance, e.g., Bloom, 1996; Keleman, 1999; Rips, 1989).

Actions comprise one aspect of an artifact's identity, but object knowledge is often insufficient without knowing what an object is called. Labels, like the nonobvious affordances of artifacts, are not specified by objects themselves. To learn a label requires hearing others produce the label, much like learning an object's intentional affordance requires seeing others act on it. Traditionally, researchers have investigated word learning and action learning as separate and largely independent developments. More recently, however, a growing body of evidence suggests that underlying both labels and actions are parallel processes that are tightly coordinated with perceptual and motor functions. For example, Smith (2005) demonstrated that children's interactions with a named novel object determine what other objects receive the same label. Specifically, when an exemplar was moved up and down, 2-year-olds selected vertically elongated objects as having the same name; when the object was moved side to side, children extended the label to horizontally elongated objects.

The notion that labels are grounded in perception and action is contrary to the more traditional idea that labels are amodal symbols stripped of their sensorimotor origins (e.g., Chomsky, 1980; Fodor, 2000; Pinker, 1994). In contrast, embodied cognition theory maintains that objects and their labels activate previously associated sensorimotor states. For example, hearing the word *Frisbee* is said to reactivate stored sensorimotor information about the actions of grasping, throwing, and catching Frisbees (Barsalou, 1999, 2008). Similar ideas are echoed in the early claims of developmental theorists such as Piaget (1952), Werner and Kaplan (1963), and Nelson (1974).

The issue we address in the present research is the nature of the developmental relation between naming and acting in the context of learning about unfamiliar objects. That is, are actions and labels mapped to objects in parallel fashion? A 2002 study by Childers and Tomasello provides initial evidence that addresses this issue. The study revealed that 2-year-old children who learned nonverbal actions for objects performed significantly better in tests of production than children who learned object names. Receptive knowledge, however, did not differ between children who learned object labels and those who learned object-based actions. The current research builds from this intriguing and largely unanticipated pattern of results to investigate in parallel fashion children's ability to map labels and actions to objects. We also asked whether the production advantage seen for actions is specific to young children or whether it also exists in adults.

In three studies, we employed a laboratory training paradigm to compare action learning to word learning. In the first study, 2- and 3-year-olds were randomly assigned to learn either nonce names or arbitrary actions for four novel objects. Measures of receptive and productive learning were recorded. Study 2 used a within-subject design to directly compare word learning and action learning in individual preschoolers over a two-day period. Study 3 trained and tested adults using a similar within-subject design. Before proceeding to these studies, we briefly consider how language and action interact in an embodied system. We then review the relevant literature on word learning and action learning. Based on these findings, we offer predictions about the relative ease with which young children might be expected to learn words and actions in our experimental training task.

## LANGUAGE AND ACTION IN AN EMBODIED SYSTEM

Mounting evidence suggests that language develops in tight coupling with perception and action (Glenberg, 2007). Before infants produce their first words, their vocal productions are closely coordinated with motor movements. For example, it has been observed that vocalizations occur in synchrony with infants' actions, particularly rhythmic arm movements (Ejiri & Masataka, 2001; Iverson & Fagan, 2004). Still other research indicates that early spoken language originates in nonverbal gestures, such that gesture-based communication predicts advances in verbal productions (Goodwyn, Acredolo, & Brown, 2000; Iverson & Goldin-Meadow, 2005). Together, these findings suggest that early linguistic developments are rooted in motor activity.

Action continues to shape children's language as word learning is directed by the morphology of the body and the actions it performs. There is a great deal of regularity, for example, between the verbs children know and regions of the body. Verbs representing actions produced by the mouth (e.g., eat, smile) emerge the earliest, followed by hand and arm actions (e.g., clap, share) and leg actions (e.g., chase, jump). In comparison, verbs that are not strongly associated with a single body part (e.g., bump, finish) are learned later (Maouene, Hidaka, & Smith, 2008). Brain imaging studies of adults also show communication between action and language systems (Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005). Stimulating motor areas in the left hemisphere that are associated with the hands speeds participants' responses in a lexical decision task when presented with hand-related verbs (e.g., pick) but not leg-related verbs (e.g., kick). Far from being independent processes, then, there is compelling evidence to suggest that language informs action and action guides language (for alternative views, however, see, Chomsky, 1980; Fodor, 2000; Pinker, 1994).

## LEARNING LABELS AND ACTIONS FOR OBJECTS

Children are remarkably skilled at learning the names of objects. Researchers report that the acquisition of a new noun can occur with impressive speed, even in the absence of clear social cues (Carey & Bartlett, 1978). For example, Halberda (2003) found that 2-year-olds need only a single, three-second exposure to establish a novel object-to-word mapping in an ambiguous labeling context. Younger children are also capable of forming rapid associations between words and their referents, although multiple ostensive exposures are necessary. In particular, Woodward, Markman, and Fitzsimmons (1994) demonstrated successful word learning in 13-month-old infants presented with a single novel referent after nine repetitions of a novel word. A similar outcome was reported by Schafer and Plunkett (1998), who presented 15-month-olds with two novel referents followed by only three repetitions.

Long before word learning is evident, newborns show an impressive ability to model the bodily actions of others (Meltzoff & Moore, 1977). As children develop the physical coordination to manipulate objects, they begin to imitate object-directed actions. For example, Hayne and colleagues have reported that 6-month-old infants recall object-specific actions (e.g., squeezing an owl to make its eyes flash) that an experimenter demonstrated at a previous session (Collie & Hayne, 1999; Herbert, Gross, & Hayne, 2006; Piaget, 1962). Others have demonstrated that infants in the first year can retain memories of actions over substantial delays. For example, infants at nine months have been shown to imitate simple actions with novel toys such as pushing

a button or rattling a small plastic egg over a 24-hour delay (Meltzoff, 1988). With delays of four to five weeks, nine-month-olds retain action memories from multistep sequences such as propping up a ramp and sliding an object down (Bauer, Wiebe, Waters, & Bangston, 2001; Carver & Bauer, 1999, 2001).

A separate line of evidence indicates that actions may also serve a communicative purpose before children express themselves verbally. Infants have been found to refer to objects using nonverbal gestures based on the actions associated with them. For example, one child was observed to wag his/her index finger to refer to a light switch; another referred to balls by using a throwing motion (Acredolo & Goodwyn, 1988). The onset of such gestural symbols occurs in advance of word production (Goodwyn & Acredolo, 1993), suggesting that children have command of action-based symbols before they label objects using spoken language. Gestures, however, lose their status in naming late in the second year when children begin to accept only words as names for things (Namy & Waxman, 1998).

Children's acquisition of the actions associated with objects is remarkably rapid, matching their skill at fast-mapping words. For example, Casler and Kelemen (2005) found that 2 1/2-year-olds formed object-action mappings on the basis of a single 1-minute exposure. In another study involving three novel objects, each paired with an arbitrary action, 2-year-olds performed at ceiling with as few as four exposures (Childers & Tomasello, 2002). Perhaps even more impressive is the resilience of the mappings between actions and objects over time relative to label-object mappings. For example, Meltzoff (1995) found that 18- and 20-month-old children imitated actions (e.g., pressing the top of a box with one's forehead) they had seen an experimenter perform as long as four months earlier. In contrast to children's robust memory for actions, Horst and Samuelson (2008) reported that although 24-month-olds were capable of selecting the correct referent from among several novel names, they were unable to retain this information after only a brief 5-minute delay.

A second intriguing dissimilarity between actions and labels concerns differences in task demands, specifically, whether the task taps receptive or productive knowledge. One well-known finding in the child language literature is that word comprehension outstrips word production in the early stages of vocabulary growth (Bates, Bretherton, & Synder, 1988; Benedict, 1979; Fenson, Dale, Reznick, Bates, Thal, & Pethick, 1994; Goldin-Meadow, Seligman, & Gelman, 1976; Harris, Yeeles, Chasin, & Oakley, 1995; Huttenlocher, 1974). More generally, it is widely believed that, across development, recognition and recall tasks place different demands on the learner. Accordingly, tasks that require children to generate a learned response, involving either words or actions, should be more challenging than tasks requiring children simply to identify a target from among several options. Contrary to this prediction, however, Meltzoff (1995) found that in studies of deferred imitation, young children had little trouble *producing* the correct motor response even after an extended delay. In contrast, children in Horst and Samuelson's (2008) word learning study failed to *comprehend* the correct referent named by the experimenter after only a short interval.

To summarize, the child development literature has treated children's mastery of words and actions as independent achievements. Yet an examination of children's ability to establish object-word and object-action mappings reveals similarities that point to corresponding development. There also are significant dissimilarities between the two domains. Initial action mappings are retained over the long term and are readily produced by the young child. Initial word mappings are fragile in the sense that they are short-lived in memory and only occasionally produced by

the child. These differences suggest that, although both labels and actions are grounded in sensorimotor states, distinct processes may operate in their acquisition. In particular, there is evidence to suggest that there may be fundamental differences in the processes of retrieval. Specifically, actions may be accessed directly from the visual perception of an object, whereas the retrieval of a label is dependent on additional information at the semantic and phonological levels (Riddoch & Humphreys, 1987; Yoon, Heinke, & Humphreys, 2002). Given a visually presented object such as a hammer, for example, the selection of an appropriate action (e.g., pounding) may be immediately accessible from visual cues. For successful naming to occur, in contrast, perceptual input must be supplemented by semantic knowledge. Our working hypothesis is that a direct visual route to action, unencumbered by lexical information, may benefit the initial mapping between an object and how it is used.

In the first of three studies, we used a laboratory training paradigm to investigate learning of labels and actions for objects in 2- and 3-year-olds. Children were randomly assigned to learn either novel names or arbitrary actions for a series of four unfamiliar objects. There were two main predictions. First, based on Piaget's theory of sensorimotor development and previous findings by Childers and Tomasello (2002), we hypothesized that children would learn arbitrary actions for objects more readily than labels for the same objects. This prediction is also consistent with theories of embodied cognition, according to which perceptual-motor inputs facilitate quick and appropriate action in the world (e.g., Barsalou, 1999; Borghi, 2005; Glenberg, 1997).

A second prediction was that children would perform better in receptive tasks than productive ones for words but not actions. This prediction was based on widespread differences in the nature of children's memory for labels and actions in the literature. Studies of early word learning typically report that children are successful in tasks of comprehension, but not production (e.g., Childers & Tomasello, 2002; Halberda, 2003; Horst & Samuelson, 2008; Woodward et al., 1994). In contrast, studies of action learning typically find that children not only understand but also produce novel actions (e.g., Meltzoff, 1995).

## STUDY 1

### Method

*Participants.* Thirty-two 2-year-olds (16 females, 16 males) and 32 3-year-olds (16 females, 16 males) were randomly assigned to either a Label Condition or an Action Condition in equal numbers. The mean age of the 2-year-olds was 24 months (range = 23–24 months). The mean age of the 3-year-olds was 41 months (range = 35–49 months). Parental consent and child assent were established prior to the start of the study. Children received a small gift (e.g., t-shirt) for their participation. An additional 13 children participated but were excluded from the final sample because of excessive fussing ( $n = 5$ ), failing to make any discernible response ( $n = 5$ ), and experimental error ( $n = 3$ ).

*Stimuli.* The stimuli were four novel objects, of diverse color and texture, ranging in size from 7.5 cm to 16 cm ( $M = 12.1$  cm). As shown in Figure 1, the stimuli included inanimate objects as well as objects that possessed eyes. Additional materials included a 35 × 45 cm plastic



FIGURE 1 Sample unfamiliar objects.

tray used during comprehension testing and a malleable red disc-shaped object (8 cm) used by the experimenter to assess receptive knowledge in the Action Condition.

Objects were randomly assigned either a novel name or an arbitrary action depending on condition (see Appendix). The novel names were composed of sounds common to children's early phonetic repertoires (Sander, 1972; Stoel-Gammon, 1985) and were either one or two syllables in length (e.g., *booma*, *oot*). Arbitrary actions were selected so that they could be performed with any one of the experimental objects. All of the actions involved manipulating one of the objects in some manner. For example, one of the actions was to pick up an object and place it on top of one's head; another was to bat an object back and forth with two hands. Arbitrary actions were used instead of actions inherent to an object's structure in order to keep constant the arbitrary nature of labels and actions. Actions related to an object's form could be inferred through an object's structure and parts rather than retrieved from memory. Randomization was an additional measure to ensure that neither labels nor actions bore any unintentional resemblance to the objects with which they were paired.

**Procedure.** Individual children were tested at a single session. Parents accompanied the 2-year-olds to the laboratory and were present during testing, but were instructed to remain silent. The 3-year-olds were removed from their preschool class to participate. All sessions were videotaped for later coding.

The session began with a training phase during which the experimenter presented each of the four objects individually and in a predetermined random order. In the Label Condition, the experimenter named each object approximately six times. For instance, the experimenter said, "This is called the *booma*. See the *booma*? Can you say *booma*?" In the Action Condition, the experimenter demonstrated the action for each object about six times, saying, for example, "This one goes like this. See what we do with it? Can you do that?" In both conditions,

children were permitted to manipulate the objects and were encouraged to produce the labels or actions on their own.

Immediately after all four objects were presented in training, children's receptive and productive knowledge were assessed. Order of testing was counterbalanced and corrective feedback was provided during both phases of testing. To measure receptive knowledge, all four three-dimensional objects were placed on a tray in front of the child. In the Label Condition, children were asked to point to objects as they were named. For example, the experimenter asked, "Where's the *booma*?" In the Action Condition, children were instructed to point to objects as the experimenter performed the corresponding actions using the malleable disc as a placeholder. For example, the experimenter asked, "Which one do we do this with?" while touching the placeholder to the top of her head.

During production testing, individual objects were presented one at a time in a predetermined random order. The experimenter elicited production in the Label Condition by asking, "What's this called?" while the child was attending to the object. In the Action Condition, the experimenter asked the child to demonstrate each object's action while the child was holding the object. For example, the experimenter asked, "What do we do with this one?"

*Coding.* Responses during the test of receptive knowledge were coded as correct when they pointed to or otherwise indicated the correct object at the request of the experimenter. To be scored as a correct production, the child's utterance had to contain at least two of the target word's phonemes in the correct position. As an example, correct productions of the word *booma* included *ooma* or *boom*. Likewise, children's action productions were coded as correct when they approximated the primary motor components of the experimental action. For example, if the experimenter demonstrated touching an object with her elbow, acceptable responses included touching the object with any part of the forearm.

Reliability was determined by having a random selection of 25% of the children in each age group rescored by a second coder trained on the coding criteria, but who was naïve to the experimental hypotheses. In the Label Condition, no disagreements were recorded in the recognition test and inter-rater agreement for productive responses was 96%. In the Action Condition, agreement between the two coders was 94% in receptive testing and 100% in production testing. The original coder's judgment was used to resolve any coding disputes.

## Results

The study began with the experimenter introducing the unfamiliar objects and either their labels or actions. Children in the Label Condition heard the experimenter produce each label an average of 8.42 times (range = 3-15). In the Action Condition, the experimenter demonstrated each action an average of 5.54 times (range = 2-7). An independent samples t-test revealed that the experimenter produced the labels more frequently than the actions in training,  $t(62) = 7.42, p < .001$ . This difference was not, however, mirrored in children's behavior during training. Children in the Action Condition generated marginally more productions for each object ( $M = 1.83, \text{range} = 0-6$ ) than children in the Label Condition ( $M = 1.30, \text{range} = 0-4$ ),  $t(62) = 1.94, p = .06$ .

Performance is reported as percent correct out of four objects. The data were analyzed using a mixed analysis of variance (ANOVA) with Condition (Label, Action) and Age (2 years, 3 years) as between-subject factors and Test (Receptive, Productive) as a within-subject factor. All three main effects reached significance: Condition,  $F(1, 60) = 112.72, p < .001, \eta_p^2 = .65$ ; Age  $F(1, 60) = 49.57, p < .001, \eta_p^2 = .45$ ; Test  $F(1, 60) = 18.58, p < .001, \eta_p^2 = .24$ . The three 2-way interactions were also significant: Condition  $\times$  Age,  $F(1, 60) = 19.00, p < .001, \eta_p^2 = .24$ ; Condition  $\times$  Test,  $F(1, 60) = 86.90, p < .001, \eta_p^2 = .59$ ; Age  $\times$  Test,  $F(1, 60) = 7.32, p < .01, \eta_p^2 = .11$ . These effects were qualified by a significant three-way interaction between Condition  $\times$  Age  $\times$  Test,  $F(1, 60) = 5.32, p = .03, \eta_p^2 = .08$ .

Simple effects were used to decompose the three-way interaction, pictured in Figures 2 a and 2b. First, the data were separated by Age and the Condition  $\times$  Test interactions within each level of Age were analyzed independently. The two-way interaction reached significance when 2-year-olds' performance was analyzed alone,  $F(1, 60) = 67.14, p < .05$ . This interaction was broken down using tests of simple effects as a function of Condition. The analysis indicated that receptive knowledge exceeded productive knowledge in the Label Condition (59.4% and 7.81%, respectively), but not the Action Condition (35.9% and 75.0%, respectively).

When 3-year-olds' performance was analyzed alone, the Condition  $\times$  Age interaction also reached significance,  $F(1, 60) = 24.49, p < .05$ . As was the case with 2-year-olds, performance in the Label Condition was marked by a significant gap between receptive ( $M = 70.3\%$ ) and productive knowledge ( $M = 15.6\%$ ). A similar asymmetry failed to emerge in the Action Condition (both 95.3%).

We also analyzed the size and direction of the gap between receptive and productive knowledge for individual children in each age group. We calculated a difference score by subtracting the number of correct responses in production from the number of correct responses in the receptive task for each child. As depicted in Figures 3 a and 3b, the difference scores have a midpoint of zero which represents the absence of a gap (i.e., receptive and productive performance were equal). Scores to the right of the midpoint represent a production lag; that is, receptive performance was greater than productive performance. Scores to left of the midpoint represent a reception lag, such that productive performance was greater than receptive performance. The dependent measure is the number of children within each category.

Word learning was predominated by a lag in production. Every 2-year-old scored higher on the receptive task than the productive task, with an average gap size of 2.38 words. Likewise, the majority of 3-year-olds (88%) continued to comprehend more labels than they said ( $M$  gap = 2.50). In the Action Condition, however, a production lag was considerably less common. Among 2-year-olds, the majority of children (75%) produced more actions than they mapped receptively ( $M$  gap = 2.25). In comparison, 69% of 3-year-olds showed no asymmetry in receptive and productive knowledge. Taken together, these results suggest that the nature of the relationship between receptive and productive knowledge differs for actions and labels. Labels are learned first in comprehension and then production, whereas actions appear to be accessible in production first.

## Discussion

The purpose of Study 1 was to test the hypothesis that children would form mappings between objects and actions more readily than those between objects and labels. Consistent with the

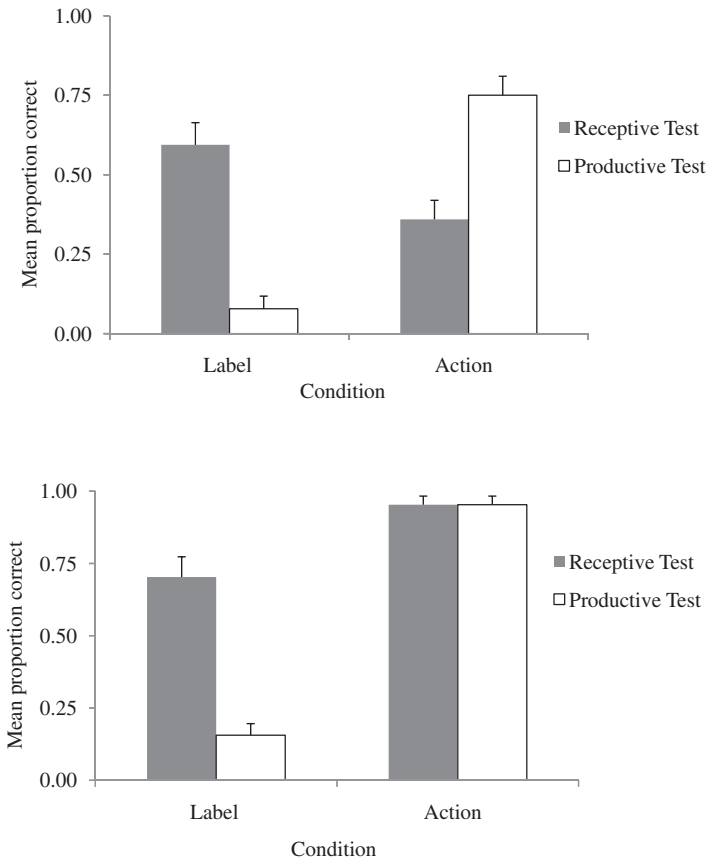


FIGURE 2 The three-way interaction between Age x Condition x Test in Study 1. (a) represents 24-month-olds and (b) represents 3-year-olds. In both cases, performance is reported as mean proportion correct.

hypothesis, the data revealed a strong advantage for action learning. The largest differences occurred in tests of production with children producing few, if any, of the experimental labels compared to nearly all of the experimental actions. It is worth noting that the advantage for action learning emerged even though the experimenter generated the labels more frequently than the actions during training, a difference that would be expected to benefit label learning. Although it is possible that small differences in children's productions in training may have contributed to their propensity to recall actions in test, this factor alone is unlikely to account for the sheer magnitude of the difference in performance between the two conditions. Rather, the results suggest that 2- and 3-year-old children are better able to access information about the actions associated with novel objects relative to their names.

The results also supported the predicted interaction between Condition and Test, such that there would be a smaller gap between receptive and productive knowledge of actions compared

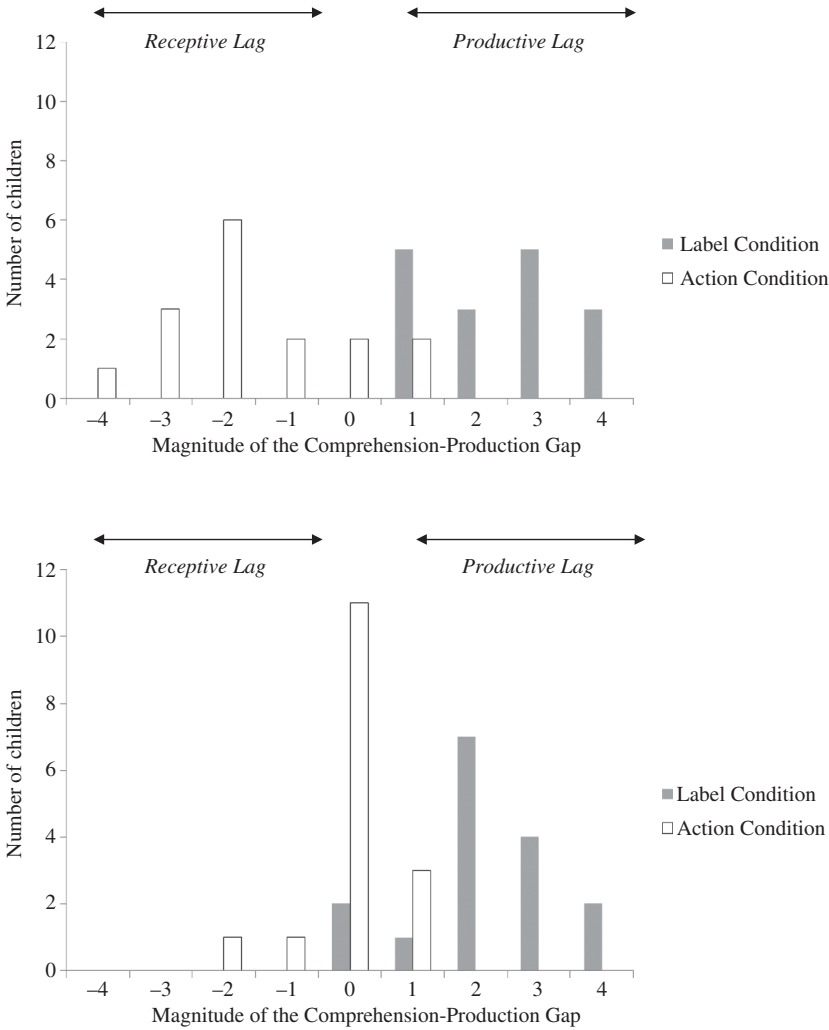


FIGURE 3 Size and direction of the gap between receptive and productive knowledge in Study 1 as a function of condition. (a) represents 24-month-olds and (b) represents preschoolers.

to labels. It is possible that the novelty of the receptive task with actions contributed to this effect. Specifically, children’s receptive knowledge of actions may have been depressed by the experimenter’s use of a generic placeholder object to produce the actions as well as the type of questioning presented to the child. Children are accustomed to hearing parents ask, for example, “Where’s your toothbrush,” but rarely do they hear a parent say, “Where’s the thing you use to brush your teeth?”

Developmentally, the results indicate that children improved only nominally in word learning compared to action learning in the ostensive training task. At two years, children produced

many more actions than labels in test, an advantage that grew larger with 3-year-olds. The extent to which children rarely produced the words they comprehended was not anticipated. The second year marks a period of rapid vocabulary growth, with children learning an average of two new words per day (Fenson et al., 1994). By the age of three, children have accumulated well over 1,000 words in their productive vocabulary and are considered to be skilled word learners (Hart, 2004; Kauschke & Hofmeister, 2002). One possibility is that the demands of the task—learning four new labels in a single session—exceeded the limits of children’s capacity to process new lexical information. However, similar demands existed in the context of learning the experimental actions: children were faced with the task of learning the same number of arbitrary actions in a single session. Yet, they did not show the same limits in processing new sensorimotor information.

In Study 2, we modified the experimental design for the purpose of directly comparing the learning of arbitrary actions and labels for individual children. The advantage of a within-subject design is that it mirrors object learning in naturalistic settings: children are often exposed to the name and function of an unfamiliar object simultaneously. As suggested by findings with infants, we predicted that word learning might be enhanced by the synchronized presentation of action and label (Gogate & Bahrack, 1998). Also in Study 2, our main focus is on the relationship between receptive and productive knowledge of words and actions. Because the 2- and 3-year-olds in Study 1 rarely produced the words they knew in comprehension, we trained and tested four- to five-year-olds and added an additional session of practice. These modifications were intended to increase the likelihood of word productions and assess whether the advantage for action learning was a result of children’s inexperience learning labels. Finally, we increased the set of experimental objects from 4 to 8 to reduce the chance that older children would perform near ceiling with action learning.

## STUDY 2

### Method

*Participants.* Thirty-two English-speaking children (16 female, 16 male) were tested in Pittsburgh, Penna., and Greenville, S.C. Children ranged in age from 48 months to 60 months with a mean age of 54 months. Data from six additional children were excluded because they were not available to complete the second session of the study. Parental consent and child assent were established prior to the start of the study. Children received a small gift for their participation.

*Stimuli.* The number of stimuli was increased to eight. Objects were randomly assigned a novel name and an arbitrary action for each child (see Appendix).

*Procedure and Coding.* The procedure was similar to that described in Study 1, with the following three exceptions. First, a second session was added to provide children with additional training opportunities. Sessions were scheduled on consecutive days. Second, objects were randomly assigned a label as well as an arbitrary action. Third, pictures of the objects, rather than

three-dimensional objects, were used in the receptive test in order to reduce possible distraction and to control for opportunities to interact with the objects. All eight pictures were presented at once in a  $2 \times 4$  matrix.

The same criteria were used for coding as in Study 1. Reliability was calculated by having a random selection of 25% of the participants in each session rescored by a second coder who was naïve to the experimental hypotheses. There were no disagreements for children's responses during the word comprehension test. Inter-rater agreement for the receptive test with actions was 99%. Agreement between the two coders was 96% for label production and 95% for action production.

## Results

In this within-subject design, children were trained on both novel labels and nonverbal actions for a set of eight unfamiliar objects. The experimenter produced each label an average of 5.27 times (range = 1-14) compared to an average of 1.26 repetitions for each action (range = 1-6). A paired-samples t-test indicated that this difference was significant,  $t(45) = 24.99, p < .01$ . Though the frequency of the experimenter's productions differed between labels and actions, children productions in training were equivalent ( $M = 1.33$  and  $1.20$ , respectively),  $t(45) = 1.36, p = .18$ .

The central question was whether four- and five-year-old children would learn actions more readily than labels when they were presented simultaneously. To address this question, children's receptive and productive knowledge of the labels and actions associated with the unfamiliar experimental objects were measured at both sessions. The results are presented as percent of correct responses out of the eight exemplars. The data were submitted to a repeated-measures ANOVA with three within-subject factors: Condition (Label, Action), Test (Receptive, Productive), and Session (1, 2). The main effect of Condition was reliable,  $F(1, 31) = 565.10, p < .001, \eta_p^2 = .95$ . Specifically, children performed significantly better when tested on actions ( $M = 86.7\%$ ) than labels ( $M = 33.9\%$ ). The same pattern emerged when individual children's performance was analyzed. Every child who was tested produced more actions than labels at both sessions. Perhaps most impressive is that by the end of Session 2, 78.1% of the children successfully produced all eight experimental actions in test. No child achieved a similar level of performance in word learning. One child produced as many as five labels at Session 2, but the majority of children (71.9%) produced two or fewer labels.

Also statistically significant were the main effects of Test ( $F(1, 31) = 77.49, p < .001, \eta_p^2 = .71$ ) and Session ( $F(1, 31) = 87.50, p < .001, \eta_p^2 = .74$ ). The results were qualified by the predicted interaction between Condition and Test,  $F(1, 31) = 120.26, p < .001, \eta_p^2 = .80$ . As shown in Figure 4, children comprehended ( $M = 52.0\%$ ) more labels than they produced ( $M = 15.7\%$ ). In contrast, children's action learning did not reveal a similar gap, indicating that actions were equally accessible to children in receptive ( $M = 85.2\%$ ) and productive tasks ( $M = 88.3\%$ ).

We also analyzed the relationship between receptive and productive knowledge for individual children in both word and action. As before, difference scores were calculated between receptive and productive performance for labels and actions at each session (see Figures 5 a and 5b).

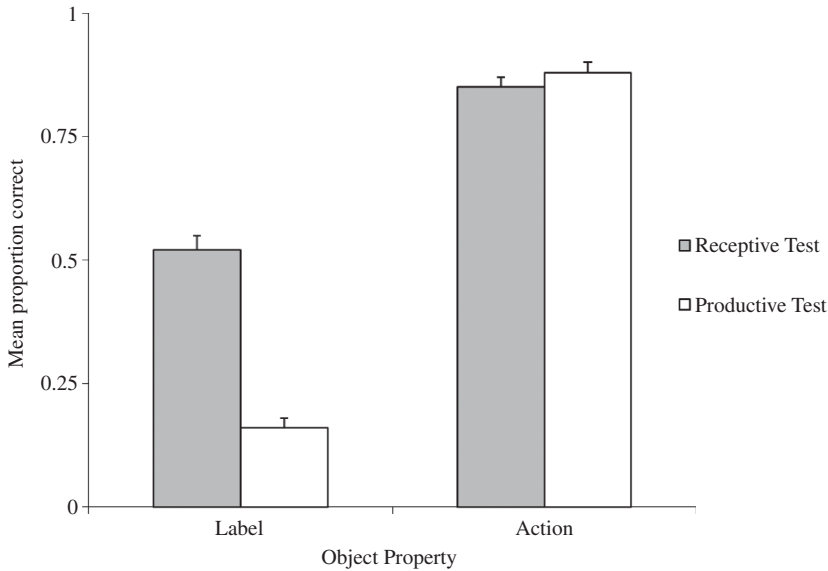


FIGURE 4 Mean proportion of labels and actions correct in test for preschoolers in Study 2, as measured in receptive and productive performance.

At Session 1, 90.6% of the children comprehended more labels than they produced, with an average gap size of 3.31 words. In action learning at the same session, difference scores were more widely distributed: 31.3% of the children demonstrated greater knowledge of actions in receptive tasks relative to productive ones ( $M$  gap = 2.10); 37.5% exhibited no lag in receptive and productive knowledge of actions; and 31.3% demonstrated produced more actions than they identified in the receptive task ( $M$  gap = 2.20). Note that the size of the gap for action learning is equivalent regardless of the direction of the relationship between receptive and productive knowledge.

By the second session of word learning, 96.9% of the children continued to show a production lag ( $M$  gap = 2.97). In contrast, only 9.4% of the children showed a similar lag for action ( $M$  gap = 1.00). For the remaining children, 50.0% comprehended and produced the same number of actions while an additional 40.6% produced more actions than they identified in the receptive task ( $M$  gap = 1.31). These results, consistent with Study 1, point to differences in the relationship between receptive and productive knowledge for words and actions. Children adhere to the common pattern of word comprehension in advance of word production. In contrast, they do not appear to follow a prescribed pattern when learning actions. Further, the results suggest that an additional session of training influences children's learning of actions and labels differently. Specifically, the initial variability in the relationship between receptive and productive knowledge for actions was reduced with a second session. In comparison, children demonstrated a highly consistent pattern of learning labels in comprehension before production over the two sessions.

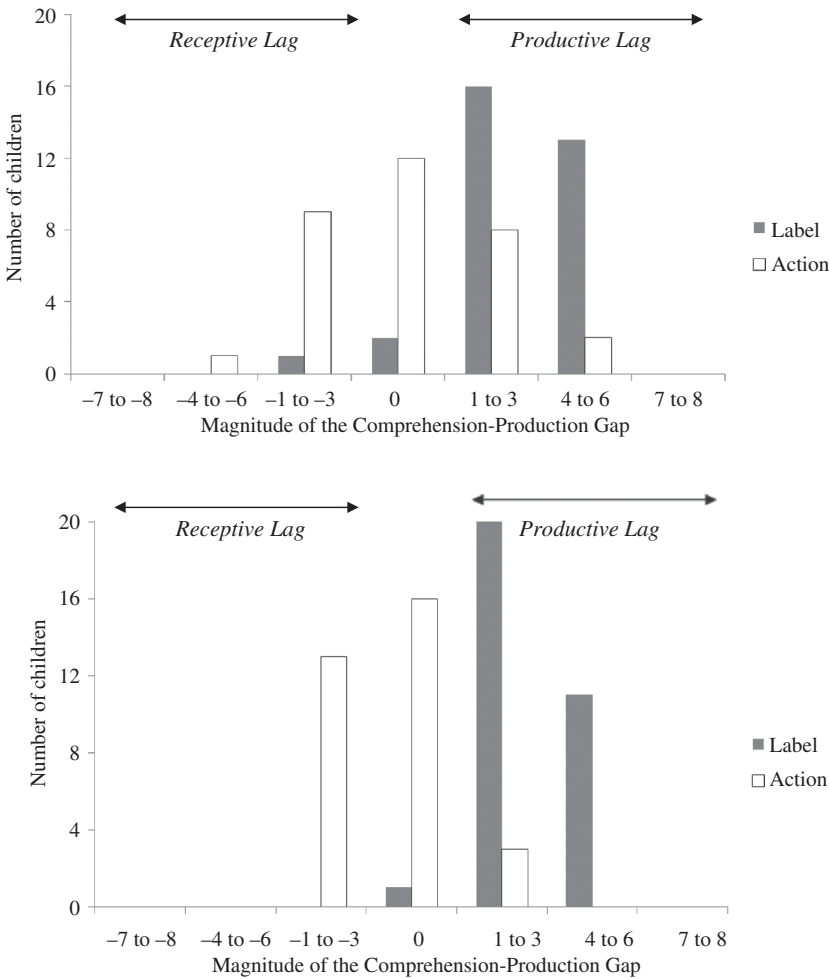


FIGURE 5 Size and direction of the gap between receptive and productive knowledge for preschoolers in Study 1. (a) represents Session 1 and (b) represents Session 2.

### Discussion

The purpose of Study 2 was to investigate the relation between receptive and productive knowledge in word and action for individual children. Consistent with Study 1, the data revealed a robust advantage for action learning among four- and five-year-olds when objects were paired with both labels and actions. The difference between actions and labels for production was especially striking: children produced 79% of the actions compared to only 7% of the labels at Session 1. In addition to replicating the advantage for action learning documented in Study 1, the results also confirm that action learning does not conform to the same asymmetries in receptive and productive performance that characterize word learning.

Even with two sessions of training, children continued to produce few of the labels in the study. One possibility is that children's low rate of word production was due to interference from action learning. Though previous work suggests that the simultaneous presentation of action and label promotes word learning in infancy (Gogate & Bahrick, 1998), preschoolers may have been drawn to the salient features of the actions relative to the words. Learning as measured in comprehension, however, suggests that children did not altogether ignore the labels in training. If actions interfered with the acquisition of label information, they did not prevent children from forming receptive mappings between objects and their labels. Moreover, children's word learning is comparable with the performance of children in the Label Condition of Study 1 when actions were not part of the task.

The finding that children excelled in their ability to map actions to objects with limited exposure supports Piaget's contention that sensorimotor information is primary in early learning. It is also consistent with the more contemporary theory of embodied cognition by which memory functions to support action in the physical environment (Glenberg, 1997). According to each of these theoretical positions, action learning may take advantage of a cognitive system that is rooted in perceptual-motor inputs. From a developmental perspective, however, these two theories make different predictions about the course of sensorimotor learning. According to Piaget, the action advantage is developmentally specific, as it reflects a nascent cognitive system fundamentally tied to perceptual-motor interactions in the physical world. From an embodied cognition perspective, the sensorimotor underpinnings of cognition are not a transitory feature of development. Rather, as Thelen (2000) argued, "[t]hinking begins in perceiving and acting and retains the signatures of its origins forever. The goal of development is not to rise above the mere sensorimotor but for cognition to be at home within the body" (p. 8). If cognition preserves ties to perception and action throughout development, as embodied cognition theory maintains, then adults would be expected to show an action learning advantage similar to the one found with children. In Study 3, we evaluated this hypothesis by testing adults using a within-subject design similar to the one used in Study 2.

### STUDY 3

#### Method

*Participants.* Twenty-four adult English-speakers (17 females, 7 males) were tested in Greenville, S.C. Participants were enrolled in an introductory Psychology course and received academic credit for their participation.

*Procedure and Coding.* The procedure was identical to Study 2 with the exception that 12 novel objects instead of eight were used to increase the demands of the task.

Coding criteria and reliability calculations were identical to those used in the previous two studies. No disagreements were coded for action comprehension responses. One disagreement was recorded for responses in each of the remaining measures: word comprehension, word production, and action production. Inter-rater agreement was calculated at 99% (range = 92-100%) for each.

## Results

Each session began with a training phase in which the experimenter produced the names and actions associated with the experimental objects. On average, the experimenter generated labels 1.07 times (range = 1-4) and actions 1.01 times (range = 1-2). Participants followed suit, repeating each label (range = 1-4) and action (range = 1-2) an average of 1.01 times each.

The data were scored as the percent of labels and actions correct in each the receptive and productive tests at two sessions. A repeated-measures ANOVA revealed a significant effect of Condition,  $F(1, 23) = 84.35, p < .05, \eta_p^2 = .79$ . Adults, like the preschoolers in Studies 1 and 2, mapped the experimental actions ( $M = 90.6\%$ ) at a higher rate than the labels ( $M = 59.9\%$ ). This advantage for action learning was supported by follow-up analyses of individual participants' performance. With a single session of training, all but one participant (95.8%) produced more actions than labels. By Session 2, 75.0% of the participants achieved perfect performance in both the receptive and productive tests for all 12 actions. In comparison, only 16.7% of the participants attained the same maximum level of performance for labels.

With respect to Test and Session, both main effects were reliable. Specifically, receptive knowledge ( $M = 82.4\%$ ) surpassed productive knowledge ( $M = 68.1\%$ ),  $F(1, 23) = 74.73, p < .05, \eta_p^2 = .77$ , and performance at Session 2 ( $M = 90.0\%$ ) exceeded that at Session 1 ( $M = 60.4\%$ ),  $F(1, 23) = 167.30, p < .05, \eta_p^2 = .88$ . Importantly, as shown in Figure 6, there was a significant interaction between Condition and Test,  $F(1, 23) = 31.26, p < .05, \eta_p^2 = .58$ . Like the children in Studies 1 and 2, receptive performance ( $M = 71.5\%$ ) outpaced productive performance ( $M = 48.3\%$ ) for labels, but not actions ( $M = 93.3\%$  and  $87.8\%$ , respectively).

We further examined the relationship between receptive and productive knowledge for individual participants. Difference scores were calculated between receptive and productive performance for labels and actions at each session (see Figures 7 a and 7b). On the first day of training, receptive knowledge exceeded productive knowledge for the majority of adults when

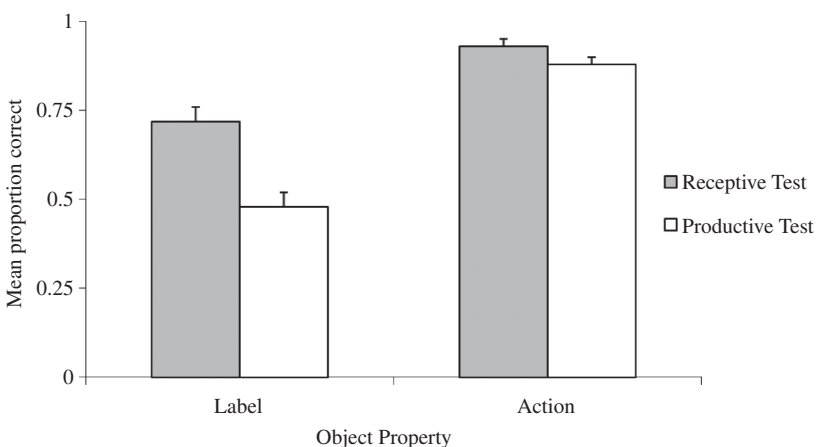


FIGURE 6 Mean proportion of labels and actions correct in both receptive and productive tests for adult participants in Study 2.

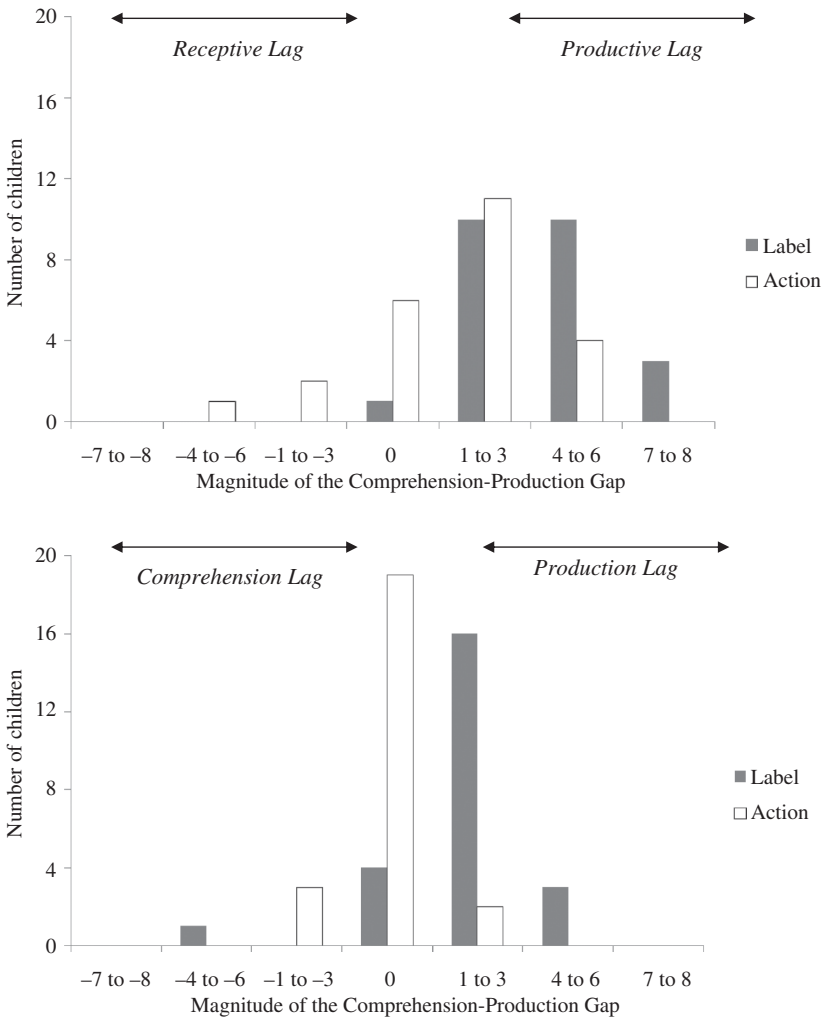


FIGURE 7 Size and direction of the gap between receptive and productive knowledge for adults in Study 2. (a) represents Session 1 and (b) represents Session 2.

tested on both labels (95.8%) and actions (62.5%). Furthermore, like the preschoolers in Study 2, the gap between receptive and productive performance was greater for labels ( $M$  gap = 4.09) than actions ( $M$  gap = 2.60). With an additional session of training, 79.2% of the participants continued to exhibit a production lag for labels ( $M$  gap = 2.37), compared to only 8.3% of the participants when tested on actions ( $M$  gap = 1.50). The majority of adults (79.2%) exhibited no lag between receptive and productive performance for action learning at Session 2. Similar to the findings of the previous two studies, the results point to differences in the size and direction of the gap between receptive and productive knowledge for labels and actions.

## Discussion

The motivating question in Study 3 was whether adults would map arbitrary actions to objects more readily than novel words, as was found with children in Studies 1 and 2. Piagetian theory and embodied cognition theory offer competing predictions. According to Piaget, perception and action are precursors to a cognitive system that gradually evolves to an abstract symbolic level. The results, however, are consistent with an embodied cognition approach, according to which perception and action continue to characterize cognition throughout development.

Also consistent with the child data, the relationship between receptive and productive knowledge was different for actions and labels. While both actions and labels were accessible receptively, the size of the gap between receptive and productive knowledge was smaller for actions. Further, with an additional session of training, the gap closed for actions, but not for words. These findings suggest that the processes underlying the production of actions uniquely benefit from information that is rooted in direct perceptual-motor experience.

## GENERAL DISCUSSION

The current research investigated the rate at which initial mappings between objects and labels and objects and actions are formed in both nascent and experienced learners. We compared the learning trajectories of words and actions when they were presented separately and again when they were presented in tandem. The purpose was to gain new insights into the basic processes that underlie core aspects of object knowledge.

We found that actions were learned more readily than labels. The effect was consistent despite variations in the age of participants tested, the training design used, and the manner in which data were analyzed. Action learning outpaced word learning when separate groups of children were assigned to learn either names or actions (Study 1), and when children were faced with the task of associating objects with both a label and an action (Study 2). Analyses of aggregate data as well as individual patterns of performance yielded the same result. With only a single session of training, the difference was large and true of virtually all participants. Adding a second session of training benefited children and adults in similar fashion; maximum levels of performance were obtained for actions, but not labels.

The findings extend the earlier work of Childers and Tomasello (2002) who found that 2-year-olds in an ostensive training paradigm produced considerably more actions than names. The present research reveals that this pattern of results is also consistent among preschooler-age children and adults and emerges no matter whether action learning and label learning are examined independently or within the same participant. Comparing 3-year-olds in Study 1 (between-subject design) with 4- and 5-year-old children in the first session of Study 2 (within-subject design), absolute measures of word learning were consistent; children comprehended approximately three labels and produced less than one. It is interesting that word learning was not affected by differences in the number of training exemplars or the age of children tested. Receptive and productive knowledge of action were at ceiling in Study 1 and remained high in Study 2 despite the increased number of exemplars.

A second important finding was that the nature of the relationship between receptive and productive knowledge varied for labels and actions, as well as across age groups. Specifically,

children and adults comprehended many more of the experimental words than they produced. Surprisingly however, an equally robust advantage for receptive knowledge did not arise in action learning. Instead, the direction of the difference between recognizing and generating a response was more variable in the context of learning to map arbitrary actions to novel objects, especially for children. When there was a gap between receptive and productive performance, it was smaller for actions than labels. Together, we interpret these findings as evidence that actions are more readily accessible in memory than words.

### AN EMBODIED COGNITION ACCOUNT

The facility with which children and adults learned actions relative to labels—particularly with respect to production—fits with contemporary theories of embodied cognition. According to these accounts, cognition is grounded in sensorimotor activity. Labels convey meaning by virtue of their association with perceptual and motor states. For the beginning word learner, labels appear to originate in sensorimotor activity (Piaget, 1952). Later in development, words derive their meaning from these very same systems (Glenberg & Robertson, 2000). The idea that actions may support knowledge of object labels is consistent with the notion that word retrieval involves the simulation of previously stored sensorimotor states (Barsalou, 1999, 2008). In this model, words belong to a network of semantic knowledge that includes, among other things, perceptual properties and actions. Knowing the actions associated with an object may boost activation in the network, resulting in improved word retrieval. Yoking labels to actions facilitates word learning in the first year of life (Gogate & Bahrick, 1998). Additional research, however, is needed to examine directly the dependencies between labels and actions in later word learning.

More importantly, however, the claim that labels and actions possess similar perceptual-motor underpinnings does not necessarily imply that they are acquired in identical fashion. Theories of embodied cognition view the primary goal of the cognitive system as promoting action in the world (Wilson, 2002). Consistent with this assertion, previous research has confirmed that action constitutes a highly accessible form of object knowledge. For example, given a picture of a ladle, adults are quicker and more accurate to respond that it is used for pouring than they are to generate its name (Chainay & Humphreys, 2002).

On a mechanistic level, the robustness of action knowledge may arise from interdependencies between perception and motor representations. Studies of adults using brain imaging techniques and behavioral data indicate that motor plans are automatically evoked upon seeing an object. Researchers report that seeing an object triggers activation in areas of the brain that are associated with the use of objects, primarily the posterior region of the left middle temporal gyrus (Chao & Martin, 2000; Grèzes, Tucker, Armony, Ellis, & Passingham, 2003; Martin, 2007; Weisberg, van Turenout, & Martin, 2007; see also Lewis, 2006, for a review). Other studies have found that simply seeing a manipulable object, without the intention to act on it, potentiates appropriate motor responses (e.g., Bub, Masson, & Bukach, 2003; Klatzky, Pelligrino, McCloskey, & Doherty, 1989; Tucker & Ellis, 1998, 2001, 2004). Participants are quicker to respond with a poking gesture, for example, when primed with a picture of a calculator rather than a beer mug (Bub, Masson, & Cree, 2008). Finally, there is evidence to suggest that even brief exposure to the function of a novel object—like that in our experimental training paradigm—is sufficient to

activate the neural areas associated with action when the objects are viewed passively at a later time (Weisberg et al., 2007). Thus, the speed with which actions were mapped to novel objects in the present research may be due to the automatic potentiation of motor representations that were initially active during training.

While the spontaneous activation of motor patterns may account for some of the ease with which action learning occurs, it is less clear why label learning appears to be considerably more difficult, particularly in the case of production. Rumiati and Humphreys (1998) have suggested that the retrieval path from object to label is less direct than the path from object to action (see also Riddoch & Humphreys, 1987). When generating the name of an object, both semantic and phonological information must be activated and retrieved from lexical memory. In contrast, action knowledge may be automatically activated upon seeing an object and does not necessitate access to either semantics or phonology. It follows that the observed action advantage in the current research might arise from an expedited route of retrieval, linking stored visual information directly to stored actions. In this way, the structure of the conceptual system may facilitate the retrieval of actions.

## THE NATURE OF WORDS AND ACTIONS IN CONCEPTUAL KNOWLEDGE

A common assumption about early word learning is that children's first nouns are learned associatively, that is, by linking together word and object (Plunkett, 1997). Later in development, as children's vocabulary reaches some critical mass, they discover the symbolic nature of words. Huttenlocher and Higgins (1978) proposed that symbolic understanding was evident when a word was understood or used in the absence of the referent being (see also Hockett, 1960; Werner & Kaplan, 1963). In the present studies, we cannot know whether adults and children learned the experimental words as symbols for the objects or mere associates.

Although it is possible to attribute the outcome of the present research to differences in how adults and children regarded the experimental words and actions, we favor the position that both label-to-object mappings and action-to-object mappings reflect associative learning processes. In our view, the key issue is not the symbolic nature of linguistic versus nonlinguistic information but rather how the coupling between the two types of mappings are differentially encoded, stored, and retrieved in light of common mechanisms of activation and competition.

From a developmental perspective, the results also speak to the nature of affordances in the emerging conceptual system. Early in development an understanding of the intentional affordances of objects can override pertinent perceptual features leading children to engage in object-directed actions that are unfeasible given an object's size (DeLoache, Uttal, & Rosengren, 2004). Before the age of three, children have been shown to attempt to sit on a chair that is only a few inches tall or step into a miniature car. Though this phenomenon is generally interpreted as evidence of an immature action-planning system, it may also emerge, in part, from the representational strength of intentional affordances (Glover, 2004). Conventional actions associated with objects may be so robust in memory that they can overshadow immediate perceptual cues. While the ability to inhibit actions prescribed by an object's affordances increases with age, there is evidence to suggest that affordances continue to be especially influential throughout development (Bub et al., 2008).

## IMPLICATIONS FOR WORD LEARNING

In the present research, we have focused on the ability to link words and actions to objects with minimal input, a skill that is known in the language development literature as fast-mapping. Though the term is widely applied, conceptual use of the term varies. As Horst and Samuelson (2008) have argued recently, fast-mapping is used interchangeably to describe the separate processes of referent selection and retention of knowledge. In the context of referent selection, fast-mapping describes how children determine to what a new label refers among multiple possible referents (e.g., Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Wilkinson, Ross, & Diamond, 2003). In contrast, the term fast-mapping is also used to describe the rapid acquisition of unambiguous input over various delays (e.g., Mervis & Bertrand, 1994; Woodward et al., 1994). Thus, in the first case fast-mapping refers to the selection of a referent, while in the second it refers to storage and retrieval of an ostensive mapping. The present work speaks to the latter use of the term, with specific regard to immediate, rather than delayed retrieval.

Studies have extended demonstrations of lexical fast-mapping to include gestures (Namy & Waxman, 1998), novel facts (Markson & Bloom, 1997), grammatical constructions (Casenhiser & Goldberg, 2005), and simple actions (Childers & Tomasello, 2002). Evidence for fast-mapping skills has also been found in nonhuman species (Kaminski, Call, & Fischer, 2004). Consistent with the present findings, these and other studies (e.g., Childers & Tomasello, 2003) challenge the notion that fast-mapping is a process that operates exclusively on linguistic input. Rather, such work demonstrates that the ability to fast-map new information reflects general cognitive mechanisms.

The current research exposed young children and adults to novel mappings involving objects and labels and objects and actions in a non-ambiguous context. Knowledge was tested both receptively and productively, following only a brief delay. Much of the extant literature focuses on children's rapid understanding of new words; however, the findings are often applied to explain children's accelerated acquisition of a productive lexicon. The present work contributes to the fast-mapping literature by demonstrating fundamental differences in the strength of label and action fast-mappings both in receptive and productive knowledge. Label mappings appear to be fragile: relatively few object words can be learned at one time and those that are retained are generally accessible only in comprehension. Action mappings, in contrast, are considerably more robust: many actions can be learned at once and most support production as well as reception. These differences suggest that not all fast-mappings are created equal; instead, the strength of the mapping depends on the nature of the information that is linked to the object. These studies are only preliminary, however; future work is needed to assess the retention of these initial mappings over various delays and to test learning in ambiguous contexts.

The results suggest that the cognitive processes that enable children to learn labels and actions for objects do not undergo a radical developmental shift. Instead, the results reveal considerable stability across adults and children. In particular, participants of all ages learned actions more readily than labels and struggled to produce the words they appeared to know in comprehension. The parallel performance of adults and children is inconsistent with accounts of development according to which cognition becomes divorced from the sensorimotor processes in which it originated (e.g., Piaget, 1952). If the early cognitive system is unique in the way it engages perception and action, then adult learners would not be expected to show an advantage for learning arbitrary actions for objects relative to labels. Instead, the results of the current research suggest

some degree of continuity in the processes involved in learning about objects. The processes that give rise to object knowledge appear to favor action-based features throughout development. A question that remains unanswered is why the production of new labels presents such a significant challenge to novice and experienced word learners alike (e.g., Gershkoff-Stowe & Hahn, in prep).

Despite these similarities, developmental change was evident in two features of the data. First, adults learned proportionally more words and actions than children and such learning occurred at a faster rate. With a single session of training, for example, adults produced on average two labels and nine actions, compared to less than one label and six actions in preschoolers. Second, the relationship between receptive and productive performance for actions varied as a function of age. At two years of age, children's action production outpaced their receptive performance. In contrast, older children did not exhibit a single predominant relationship between receptive and productive knowledge for actions. When adults were tested, however, performance in the receptive task surpassed production. These aspects of change indicate that the processes involved in learning labels and actions are sensitive to general developments in memory and other cognitive operations. The inconsistent patterns of receptive performance for children may be attributed to the symbolic demands of using a generic placeholder to perform the actions.

## CONCLUSIONS

Children must learn what the objects in their environment are called and how they are used. From an embodied cognition perspective, the physical structure and functioning of one's body affects cognitive processes and representations. The action advantage that we document provides a new and compelling piece of evidence that physical interactions with objects constitute a remarkably accessible form of memory—one that is unparalleled by word learning, a feat at which children are notoriously skilled. For both adults and children, learning how to interact with objects is a highly developed facility in a cognitive system built from sensorimotor parts.

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APPENDIX NOVEL LABELS AND NONVERBAL ACTIONS USED IN STUDY 1 AND  
 ADDITIONAL LABELS AND ACTIONS USED IN STUDIES 2 AND 3

<i>Labels</i>	<i>Actions</i>
<i>Study 1</i>	
Booma	Hold object in front of mouth and blow on it
Oot	Place object on head
Peeb	Bat object back and forth between two hands
Tata	Touch object to object as it sits on table
<i>Studies 2 and 3</i>	
Bek	Hide object behind back
Deet	Walk object forward and back on table
Dow	Using one hand, swoop object through air
Ibby	With object on table, cover with two crossed hands
Mig	Make object jump vertically
Mup	Touch object to nose
Pimmel	Pat object with one hand while on table
Tam	Rotate object in air using two hands