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## Everyday interactions support toddlers' learning of conventional actions on artifacts

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### ABSTRACT

Children learn to perform actions on artifacts in their environments from infancy, but the ways caregivers support this learning during everyday interactions are relatively unexplored. This study investigated how naturalistic caregiver-child teaching interactions promoted conventional action learning in toddlers. Caregivers of 32 24- to 26-month-old children taught their children to perform novel target actions on toys. Afterward, an experimenter blind to the toys children had been taught tested children's action learning. Results indicated that children's propensities to assemble objects and vocabularies were positively associated with learning. Whereas caregivers' speech did not directly support learning, caregivers' action performance negatively related to children's learning. Importantly, children's own actions related to learning: Children who performed proportionally more actions relative to their caregivers with higher action accuracy demonstrated better learning of the taught material. Thus, children who "drove" the teaching session and were more accurate in their actions learned more. Caregivers contributed by supporting their children's actions: Caregivers who provided more specific instructions and praise had children who were more active during instruction. Importantly, analyses controlled for child-level individual differences, showing that beyond children's own skills, active experience supported by caregiver guidance related to conventional action learning. These findings highlight children as central agents in the

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learning process and suggest that caregivers contributed by coaching children's actions.

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## Introduction

Infants are surrounded by cultural artifacts in daily life; telephones, forks, and books have specified uses that social partners pass on to children via cultural transmission (Legare, 2019). Learning appropriate actions on artifacts is crucial for becoming a culturally competent member of society and is uniquely human given that no other species use objects the way humans do (Tomasello, 2001). How do infants learn to perform conventional actions on artifacts? Cultural artifact use is like language in that it develops early and might not be learned through independent discovery alone. Although much is known about properties of adult input supporting language development, little is known about the everyday learning contexts that facilitate children's understanding of culturally defined actions on objects (e.g., turning pages in a book, scooping food with a spoon), here referred to as *conventional actions*.

Conventional action learning begins early. By 6 months of age, infants understand uses for common objects (e.g., cups are used for drinking; Hunnius & Bekkering, 2010). Similarly, 9-month-old infants begin using culturally relevant objects such as spoons (Keen, 2011) and can solve toy retrieval problems using simple tools (Bates, Carlson-Luden, & Bretherton, 1980). How do infants learn to perform actions on artifacts in their environments? Although children act on objects without guidance through trial-and-error learning, they might not arrive spontaneously on culturally appropriate actions without some form of adult support. Cultural experts such as caregivers may incidentally provide action demonstrations while children observe, or adults may directly instruct children (Legare, 2019). However, the nature of everyday caregiver input and the role children may play in this learning process is relatively unstudied.

### *Adult input supports object learning*

Analogous to language acquisition, in which adult input is necessary (Kuhl, 2007), viewing adults demonstrate conventional actions allows infants to see high-fidelity representations of material to be learned. From early in life, infants are keen imitators of adult actions in laboratory settings (Bandura, 1977; Tomasello, Kruger, & Ratner, 1993). Indeed, by 9 months of age infants imitate simple actions on objects (Meltzoff, 1988), and by the end of the first year of life infants imitate two-step action sequences (Bauer, 1996) and more complex three-step action sequences (Elsner, Hauf, & Aschersleben, 2007). In addition, adult demonstrations seem to be particularly important for learning when an object's function is opaque and cannot be discovered through infants' activity alone. For example, 12-month-old infants learned to perform actions on artifacts (e.g., removing a cap from a cylinder) after viewing demonstrations but not from their own unguided manual exploration (Fagard & Lockman, 2010). Similarly, 18-month-old infants' independent actions were insufficient for action learning; infants needed to view demonstrations to learn to use simple tools (Rat-Fischer, O'Regan, & Fagard, 2012). In these instances, infants did not stumble on conventional actions through trial and error; they needed demonstrations to guide their action learning. Clearly, infants *can* learn through imitating demonstrations, but it is unknown whether natural interactions with caregivers follow the same structure as lab-based learning (i.e., adult demonstration followed by infant imitation).

In the lab, adult demonstrations may feature cues that further bolster infant action learning. Infant imitation was boosted when actions were demonstrated intentionally (Carpenter, Akhtar, & Tomasello, 1998) or were demonstrated by a reliable person (Poulin-Dubois, Brooker, & Polonia, 2011) who made his or her goal clear (Esseily, Rat-Fischer, O'Regan, & Fagard, 2013) or included pedagogical cues indicating an intention to teach (Csibra & Gergely, 2009). However, pedagogy does not

uniformly enhance imitation in all learning contexts (Shneidman & Woodward, 2015). In addition, infant-directed action (IDA), or the natural way caregivers modulate actions when demonstrating for infants, enhanced toddlers' action imitation (Williamson & Brand, 2014). Certain features of IDA may be particularly beneficial. For example, the distance at which caregivers performed actions relative to children improved infants' subsequent action imitation (van Schaik, Meyer, van Ham, & Hunnius, 2020). However, not all elements of IDA uniformly enhance infants' conventional action learning (van Schaik et al., 2020). Although employing these interaction features in lab demonstrations benefits conventional action learning, we know relatively little about whether adults similarly modify their demonstrations during everyday interactions.

It should be noted that enhancing *imitation* is not equivalent to promoting *learning*. Adult demonstrations may generate pragmatic cues, such as promoting infants' social motivation, without necessarily enhancing conventional action learning (Shneidman & Woodward, 2015). Although children may need information from social partners about conventional actions, it is an open question whether that information is transmitted via demonstrations (with or without additional cues) in everyday contexts and whether such demonstrations promote action *learning* beyond social imitation.

#### *Features of everyday interactions support engagement*

In natural interactions outside of the lab, adults use strategies that modulate infants' *engagement with* and *attention toward* artifacts. Still, it is unknown whether these features, including language and physical strategies, enhance conventional action *learning*. Specifically, caregiver speech that was supportive (Hustedt & Raver, 2002) and contingent, cognitively stimulating, and autonomy promoting (Mermelshtine & Barnes, 2016) boosted infants' object engagement. Caregivers' physical strategies similarly enhanced infant engagement, including positioning and modeling objects (Bigelow, MacLean, & Proctor, 2004), transferring objects to children (Luo & Tamis-Lemonda, 2016), and requesting that infants engage with objects (Contaldo et al., 2013). Although caregivers use these interaction strategies in everyday contexts, it is unknown whether such strategies promote conventional action *learning* beyond influencing infants' object attention and engagement.

#### *Active experience enhances learning*

Adult demonstrations seem to be important for learning conventional actions; however, children's active engagement also plays a role in learning (Piaget, 1964). For example, infants who were given object grasping training while wearing sticky Velcro mittens subsequently explored objects in more sophisticated ways than those without mittens training (Needham, Barrett, & Peterman, 2002). Infants' independent manual exploratory skills were also related to their understanding of three-dimensional objects (Soska, Adolph, & Johnson, 2010). Furthermore, infants' own actions, but not observation of others' actions, benefitted their interpretation of others' goal-directed actions (e.g., Gerson & Woodward, 2014). Thus, active experience seems to be important for infants' artifact exploration, object understanding, and interpretation of others' actions. However, studies have yet to test whether infants' active experience facilitates learning of conventional actions in everyday contexts.

Although such studies are lacking in infants, research with older children suggests that active experience may enhance action learning. For example, 4-year-old children who recalled performing more actions themselves subsequently reconstructed taught artifacts with greater accuracy (Sommerville & Hammond, 2007). Similarly, active experience, not observing demonstrations, enhanced 2.5- to 3.5-year-olds' learning of causal affordances of a novel object (Yuniarto, Gerson, & Seed, 2020). Initial independent experience prior to instruction is also important for learning beyond the artifact domain. Indeed, children given exploratory experience before being instructed had enhanced performance in math (DeCaro & Rittle-Johnson, 2012), science (Dean & Kuhn, 2007), and causal reasoning (Sobel & Sommerville, 2010). Although active experience boosts learning in older children, it is yet unknown whether and how such experience supports conventional action learning in young children.

Enactment matters for action learning; however, adult guidance may still be beneficial for learning culturally specified conventional actions. Cultural norms specify appropriate actions on artifacts, and infants might not stumble on these actions without observing demonstrations by a cultural expert

(Bandura, 1977; Bruner, 1972; Rogoff, 1990). Infants may also need support from a competent partner to guide their actions toward those that have been defined by culture as correct (Tomasello, 1999; Vygotsky, 1980; Wood, Bruner, & Ross et al., 1976). Thus, we might expect that adults would play an important role in supporting and guiding infants' actions. In that way, some combination of caregiver action performance, infant activity, and supportive adult guidance may promote conventional action learning during everyday interactions. Yet, it is unknown whether these interaction patterns play out during the course of everyday caregiver–child interactions or whether supported active experience benefits conventional action learning.

### *The current study*

This study examined early-emerging learning of novel conventional actions in everyday interactions. We quantified properties of caregiver–child interactions that give rise to action learning outside of scripted lab interactions by first examining how caregivers taught their toddlers to perform conventional actions and then testing toddlers' subsequent learning. Caregivers of 24-month-olds were asked to naturally teach their children to perform a series of novel target actions on a set of toys. We developed these toys with prescribed actions to address three important features, namely that (a) children would not spontaneously perform the target actions we asked caregivers to teach, (b) caregiver instruction could generate action learning, and (c) children would demonstrate variability in learning. Although the target actions to be learned were novel, the toys were similar to toys children might encounter every day, thereby balancing comfort with familiar playful learning situations with specific learning goals (novel prescribed actions). Following instruction, toddlers were tested on their knowledge of the target actions they had been taught as well as their propensity to construct a set of matched toys for which no instruction had been given. This design allowed us to evaluate the features of natural teaching sessions that related to children's action learning.

We hypothesized that variation in caregiver behavior would relate to children's learning. In particular, caregiver performance of target actions seems to be ripe for promoting learning because these actions reflect the material to be learned, providing opportunities for information transfer. Therefore, we coded caregiver action performance and fidelity. In addition to action performance, caregiver guidance also may influence learning. For example, early-school-aged children performed more accurate actions following caregiver instruction featuring elaborative guidance rather than directive guidance (Eason & Ramani, 2017), pedagogical language (Winsler, Diaz, McCarthy, Atencio, & Chabay, 1999), and fewer commands and corrections (Winsler, 1998). In addition, praise (praise on effort: Gunderson et al., 2018), labeling (Luce & Callanan, 2010), contextual information (Eason & Ramani, 2017), and highlighting the task goal (Esseily et al., 2013) are types of caregiver speech that might enhance learning. As such, we coded and categorized caregiver speech during instruction to test whether certain types of language related to children's learning. Although prior research suggested that IDA might benefit learning (Williamson & Brand, 2014), this study lacked an adult-directed action comparison and we observed little variability in action exaggeration or speed; thus, IDA was not measured.

Whereas caregiver action performance and speech seem to be important for learning, it is possible that children's own actions also would support learning. When children learn to perform actions, action practice seems to be relevant; indeed, practice benefitted infants' multifunctional tool learning (Barrett, Davis, & Needham, 2007). Yet, relatively little is known about whether action experience promotes learning in toddlers, particularly when learning specified actions. Thus, we measured children's target action performance during instruction to test whether active experience related to learning. When coding children's target action performance, we included children's attempts to perform actions and quantified children's action accuracy for each attempt. However, because the actions to be performed on the toys were opaque, children might not spontaneously discover them—and if they did, children might not know which actions were the target actions. Caregiver guidance of children's activity may be necessary for learning. Therefore, we also measured how caregiver speech might relate to toddlers' actions. In sum, both caregiver and child contributions to instruction were measured in relation to children's learning.

We had three hypotheses for the current study. (1) Caregivers' performance of target actions would enhance children's action learning because viewing caregiver actions provides children with information about the material to be learned. (2) Children's own target action performance would be important for learning because it offers opportunities to practice actions. (3) Caregivers' speech would influence both children's learning and children's action performance. Although prior literature suggests all these strategies could be beneficial, this study is unique in that it tested whether these strategies actually occurred during everyday interactions and whether they supported action learning.

## Method

### Participants

32 toddlers (average age = 23.4 months, range = 22.1–26.2; 17 boys) participated in the study with a primary caregiver (30 mothers, 1 father, and 1 grandmother). Families were recruited from a database to participate in a lab at a large research university. Nearly half of the caregivers listed their children's race as European American ( $n = 15$ ); African American ( $n = 6$ ), Asian American ( $n = 3$ ), Hispanic or Latin American ( $n = 3$ ), or two or more races ( $n = 5$ ). Children who heard English at least 75% of the time were invited to participate because the study was conducted in English, although caregivers of 11 children reported that their children heard another language at home or daycare. All caregivers spoke primarily English to their children during the study. Maternal education was high: 16 postgraduate degrees, 9 bachelor's degrees, 3 associate's degrees, and 4 attended some college. All children were born full-term (within 3 weeks of their due date). An additional 7 children were tested but excluded from analyses due to hearing more than 25% of another language at home ( $n = 2$ ), prematurity ( $n = 2$ ), developmental delay ( $n = 1$ ), refusal to play with at least four of the six test toys ( $n = 1$ ), or experimenter error ( $n = 1$ ).

### Procedure



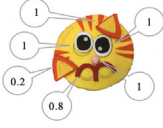


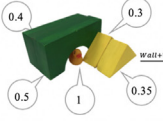



Prior to participation, the experimenter obtained informed consent from caregivers and caregivers completed a background questionnaire about their children's language exposure, children's race, and caregivers' education. Caregiver-child dyads then participated in two phases of the study: *teaching* and *test*. During teaching, caregivers taught children to perform a set of novel target actions on three multistep toys (*taught toys*). At test, the experimenter, who was blind to the toys children had been taught, tested children's action learning on the three taught items and three untaught control items (*control toys*). During test, caregivers completed the MacArthur-Bates Communicative Development Inventory, Short Form, Level II (MCDI), a checklist of words children said, to assess children's verbal skills (Fenson et al., 2000). Video was recorded simultaneously from three wall-mounted webcams, and audio was recorded from a single webcam. Following the study, children were awarded a certificate and given a book, toy, or T-shirt. Caregivers were given \$20 as compensation. The entire visit lasted approximately 1 h. Videos and coding manuals can be found online in the Databrary video repository (<https://nyu.databrary.org/volume/1321>).

### Toys

Six toys were used in the study, two per category (*puzzle*, *routine*, and *block*; see Table 1). These toys allowed dyads to interact in a familiar playful context while introducing novel material to be learned (*target actions*). Toys were designed to meet three key features, namely that (a) children did not spontaneously perform the target actions on the toys, (b) children could learn the actions through caregiver instruction, and (c) children demonstrated variability in action learning. We did not attempt to equate taught actions for motoric difficulty. Instead, we ensured that all actions were equally learnable by children. Although the toys were similar to those children might encounter every day, each toy had a set of novel target actions (*action types*) to be learned that children would not perform spontaneously without instruction. Although there are many ways to play with toys, caregivers were told to teach

**Table 1**

Toys: Action types and action attempt accuracy.

Category	Toys and action types		Action attempt accuracy:	
			Teaching – Best performance score	Test – Test score
Puzzles	<p>Cat</p>  <ol style="list-style-type: none"> <li>1. Eye 1</li> <li>2. Eye 2</li> <li>3. Ear 1</li> <li>4. Ear 2</li> <li>5. Nose</li> <li>6. Mouth</li> </ol>	<p>Snowman</p>  <ol style="list-style-type: none"> <li>1. Bottom</li> <li>2. Middle</li> <li>3. Arm 1</li> <li>4. Arm 2</li> <li>5. Hat</li> <li>6. Scarf</li> </ol>	 $\frac{\text{Eye} + \text{Eye} + \text{Ear} + \text{Ear} + \text{Mouth}}{5} = \frac{1 + 1 + 1 + 1 + 2 + 0}{5} = \frac{6}{5} = 0.83$	
	<p>House</p>  <ol style="list-style-type: none"> <li>1. Wall 1</li> <li>2. Wall 2</li> <li>3. Roof 1</li> <li>4. Roof 2</li> <li>5. Animals</li> </ol>	<p>Bridge</p>  <ol style="list-style-type: none"> <li>1. Rectangle 1</li> <li>2. Rectangle 2</li> <li>3. Triangle 1</li> <li>4. Triangle 2</li> <li>5. Drive cars</li> </ol>	 $\frac{\text{Wall} + \text{Wall} + \text{Roof} + \text{Roof} + \text{Animal}}{5} = \frac{0.4 + 0.3 + 0.35 + 0.35 + 1}{5} = \frac{3.45}{5} = 0.51$	
Routines	<p>Fruit salad</p>  <ol style="list-style-type: none"> <li>1. Colander</li> <li>2. "Wash"</li> <li>3. Break</li> <li>4. Bowls</li> <li>5. "Eat"</li> </ol>	<p>Sandwich</p>  <ol style="list-style-type: none"> <li>1. Napkins</li> <li>2. Stack</li> <li>3. Plates</li> <li>4. "Eat"</li> </ol>	 $\frac{\text{Colander} + \text{Wash} + \text{Break} + \text{Bowls} + \text{Eat}}{5} = \frac{0.5 + 1 + 1 + 0.95 + 0}{5} = \frac{3.45}{5} = 0.49$	

Note. Category: Toy category (puzzles, blocks, routines). Toys and actions types: Each cell shows the final configuration of each toy and lists the associated action types. Performing these action types created the final configuration. Action attempt accuracy: Action attempts were scored for accuracy. Each cell shows an example of scoring action attempts. The most accurate attempt of each action type was averaged to yield one score per toy (maximum score: 1 point). During test, this score was children’s test score (taught test score and control test score). During teaching, this score was calculated separately for the caregiver and the child (child best performance score and caregiver best performance score) to reflect accuracy in action performance during teaching.

their children to perform the target action types. In this way, we aimed for the target actions to resemble conventional actions children learn to perform on artifacts in their environments every day.

Each toy had a set of pieces, and the target actions were performed on the pieces to assemble the toy or reach a final configuration. Puzzle toys had pieces to be assembled into a configuration (*cat* or *snowman*; six action types each). Block toys had pieces that were assembled into a structure (*house* or *bridge*), with two characters used in or on the structure (five action types each). Routine toys were wooden food items assembled to create a food product (*fruit salad* or *sandwich*), followed by a pretense action (“eating” the food; five or four action types, respectively). For both teaching and test, toy pieces were arranged on trays in identical configurations.

Children were randomly assigned to be taught one toy from each category during teaching and were tested on all six toys at test; thus, they were tested on the three toys they had been taught (*taught items*; e.g., cat, house, and fruit salad) and three matched items they had not been taught (*control items*; e.g., snowman, bridge, and sandwich). Although both items within each toy category had the same number of action types (e.g., six action types on the cat and snowman puzzles), skills learned on one toy within the category were not designed to transfer to the other toy. For example, to build the

**Table 2**  
Teaching and test measures.

Teaching		Description of measure
<i>Caregiver contributions</i>	<i>Child contributions</i>	
Instructional time		Amount of time caregivers spent teaching
<i>Actions</i>	<i>Actions</i>	
Caregiver count of target actions	Child count of target actions	Total number of actions performed across action types; total activity
Caregiver proportion of target action types	Child proportion of target action types	Proportion of different action types performed out of total possible action types
Caregiver best performance score	Child best performance score	Accuracy in attempting target actions (averaged across highest scoring attempt of each action type)
Number of complete action iterations		Number of caregiver-initiated rounds of performing all action types
	Child Share of Target Actions (Child Count of Target Actions / (Child + Caregiver Count of Target Actions))	Proportion of actions the child performed relative to the caregiver; extent to which the child “drove” the interaction
<i>Speech</i>		
Total speech		Total utterances across all speech categories (including behavior management, other, and inaudible)
<i>Speech category</i>		
Step-by-step speech		Action-relevant speech
Goal speech		Broad task-relevant speech
Label speech		Labeling, describing, etc.
Context speech		Abstract information not relevant to actions or the task
Praise speech*		Reinforcing or congratulatory speech
Correction speech*		Guidance to fix the child’s behavior
<i>Test</i>		
<i>Test score</i>		
Taught test score		Accuracy in target action performance on taught toys; learning
Control test score		Accuracy in target action performance on control toys; target action discovery and toy construction propensity
Child count of target actions (test)		Total number of actions performed across action types; total activity

Note. Teaching and test measures for caregivers and children that were used in analyses are shown; descriptions of measures are provided in the last column. Coding categories and subcategories are italicized. Codes are listed under the italicized category or subcategory.

\* Code could be combined with other speech categories. See online [supplementary material](#) for all measures coded for descriptive purposes.

cat puzzle children placed pieces onto the face, whereas to build the snowman puzzle children built pieces upward to create the final product. Thus, actions learned on taught items would not transfer to control items. Instead, performance on control items reflected (a) a baseline of target action discovery (i.e., how often children “stumbled on” target actions through trial and error without instruction) and (b) individual differences in children’s propensity to assemble toys into structures (rather than performing other actions with the toys). Thus, performance on control items could be compared with



performance on taught items to test whether children learned from instruction as well as provide a measure of children's construction propensity.

### Teaching

Prior to teaching, the experimenter explained that caregivers should teach their children naturally to perform a set of target actions on the toys. The experimenter told caregivers to *teach* because piloting revealed that when caregivers were told to *play*, they were less likely to teach the target actions. Caregivers were told they could teach for a few minutes per toy, after which the experimenter would return to see how accurately children could perform the target actions. A trained assistant then showed caregivers an instruction binder containing pictures of three randomly assigned toys (one puzzle toy, one routine toy, and one block toy in a pseudorandomized order) and explained the associated target actions. For example, the cat toy was explained as follows: "For this toy, you get to make a cat face! All the pieces Velcro on, so you just stick on the eyes, ears, nose, and mouth to make the face." The binder also contained brief written instructions about the target actions (e.g., "The ears go on top"; see online [supplementary material](#)). Caregivers could reference the instruction binder during teaching. The assistant then presented each toy individually, and caregivers taught until 5 min had elapsed or caregivers indicated they were finished, whichever occurred first.

### Test

The experimenter, blind to the toys children had been taught, tested children on their ability to perform the taught actions on the three taught items (for which instruction had been given) and their propensity to perform actions on the three control items (for which no instruction had been given). Toys were presented in a pseudorandom order such that no two toys of the same category were tested in a row and no more than two taught toys were tested in a row. Caregivers sat behind their children while completing questionnaires and were instructed not to intervene. The experimenter tested children on each toy individually by using scripted prompts to remain neutral and avoid assisting children. For each toy, the experimenter asked children "What should we do with this one?" to ensure that children knew they were supposed to perform specific actions rather than play however they chose. Children were tested for 2 min per toy or until children indicated that they were finished, whichever occurred first.

### Coding

Teaching and test videos were coded offline by trained coders using Mangold INTERACT software ([Mangold International, 2017](#)). Prior to coding, coders were trained by the first author and practiced coding with a subset of videos using a detailed manual (available on Databrary: <https://nyu.databrary.org/volume/1321>). Any uncertainty in coding was resolved through discussion with the first author. Coders coded test prior to teaching to remain blind to teaching during test coding. See [Table 2](#) for a list of all codes in teaching. See online [supplemental material](#) for a table of all codes used for descriptive purposes.

### Test coding

Children's action performance at test was coded to measure learning (taught items) and target action discovery and action construction propensity (control items). All child target action attempts were coded by action type and accuracy during the 2 min after children first touched the toy. When a child attempted a target action, it was coded for action type (e.g., cat: eye 1, eye 2, ear 1, ear 2, nose, mouth) (see [Table 1](#)). A target action was defined as a goal-directed movement of a piece to a location (e.g., placing ear 1 on the cat face base) with a clear completion of movement (e.g., ear 1 remained on the cat face base for at least 1 s).

Each target action attempt was scored for accuracy with a maximum of 1 point per action. Target action attempts on puzzles received higher scores when pieces were placed closer to their correct locations (see [Table 1](#)). For example, on the cat, placing an ear in the upper right corner of the face would score 1 point, but placing an ear on the lower portion of the face would yield a lower score (0.2). Assigning block target action attempts a numerical score for accuracy also accounted for each



piece's orientation, relation with other pieces, and whether it was the first piece placed in the block configuration. For example, on the house, placing a roof piece on top of and across both wall pieces yielded a higher score (1 point) than placing a roof next to a wall (0.3). Routine target action attempts were assigned scores accounting for the number of pieces used in each action type. For example, on the fruit salad, children scored higher on the action type "fruit in colander" when they placed more of the fruit in the colander (e.g., all fruit pieces: 1 point; six pieces: 0.54).

Because children often attempted each action type more than once, children's highest scoring attempt of each action type was used to generate test scores. For example, if a child received 1 point for placing ear 1 but only 0.2 on the next placement of ear 1, the higher score of 1 point would be used for the ear 1 action type score. The highest scoring attempt of each action type was then averaged to yield a test score for each toy. Higher test scores indicated that children performed more target actions with greater accuracy than children with lower test scores.

Children received test scores on both taught and control toys. *Taught test scores*, or children's scores on items they had been taught, reflected their learning from caregiver instruction. Children who performed more target actions with higher accuracy received higher taught test scores. Children's performance on the control items they were not taught was coded and scored analogously to taught test scores to yield *control test scores*. Although children had not been taught the target actions on control toys, if they attempted actions that were scorable target action attempts, actions were assigned scores in the same way as on taught items. For example, although a child taught the cat puzzle never received instructions on the snowman puzzle, if she happened to put a snowman arm in one of the body holes, she would receive credit for that untaught action. In that way, children who configured toy pieces in scorable ways (e.g., stacking pieces) rather than performing other actions (e.g., banging pieces together) received higher control test scores. Untaught action attempts on control items yielded control test scores that reflected both children's spontaneous discovery of target actions and children's propensity to assemble toys. In addition to calculating test scores for each toy, we also counted the total number of target actions children performed for a measure of *child count of target actions (test)*, which reflected children's overall activity across action types.

Test performance was coded and analyzed prior to coding teaching to ensure that the toys met three criteria, namely that (a) children did not perform target actions spontaneously on control toys, (b) children learned to perform target actions through caregiver instruction, and (c) learning was variable across children. As detailed in Results, these criteria were not met for routine toys. Therefore, we coded the teaching sessions for puzzle and block toys only.

### *Teaching coding*

We coded caregiver and child contributions to teaching to understand whether caregivers' or children's behaviors during instruction related to children's test performance. Caregivers contributed by (a) teaching for more time, (b) performing target actions (the material to be learned), and (c) talking to children. Children contributed by (a) bringing their underlying abilities to the session and (b) performing actions on the toys (practicing the material to be learned).

*Caregiver contributions to teaching. Instructional time.* More exposure to instruction and target actions during teaching could relate to children's learning. To measure the amount of time caregivers spent teaching, *instructional time* was coded. Instructional time reflected the amount of time caregivers were on-task and teaching their children. All additional teaching coding was performed during instructional time.

*Actions.* Caregiver performances of target actions were conceptualized to be demonstrations of the material to be learned. Caregiver actions during teaching, therefore, were coded for action type and accuracy on each action attempt. Because caregivers performed the same target actions during teaching as children did at test, caregiver actions were coded in the same way as child actions. However, caregiver actions during teaching were presentations of instructed information, whereas children's actions at test reflected their learning. The total number of actions across action types that caregivers performed or attempted on each toy was counted for a measure of *caregiver count of target actions*, which reflected total caregiver activity. We also calculated *caregiver proportion of target action types*, which measured the different action types caregivers performed, by dividing the number of action

types performed by the total number of action types possible for each toy. For example, if a caregiver placed eye 1 twice, eye 2 three times, and the nose twice on the cat puzzle, the caregiver count of target actions would be 7, but the caregiver proportion of target action types would be 0.5 because only three of the six action types were performed.

Each action attempt was given a numerical score reflecting accuracy in the same way as children's action attempts were scored at test. Analogous to generating children's test scores, caregivers' highest scoring attempt of each action type was averaged to yield a *caregiver best performance score* on each toy. This score was calculated in the same way as children's test scores, but it reflected caregivers' action performance accuracy during teaching. As with test scores, higher caregiver best performance scores indicated that caregivers performed target actions with greater accuracy than those with lower scores.

Caregivers could have also chosen to repeatedly instruct their children on the full set of target actions multiple times; therefore, *number of complete action iterations*, or complete series of performing all action types, was counted for each toy. To be coded as a complete action iteration, caregivers initiated repeating the target actions, although the actions in each iteration could be performed by caregivers or children. For example, after completing all target actions on the cat puzzle, a caregiver could say, "Let's make the cat again!", which initiated a new iteration of performing the target actions.

*Speech.* To code caregiver speech, utterances were identified, transcribed, and assigned a speech category, which reflected types of guidance that were hypothesized to relate to children's learning: step by step, goal, label, context, praise, and correction. Step-by-step utterances were specific to the actions to be learned, whereas goal utterances referred to the task more broadly. Caregivers could provide more information about the task by labeling objects or providing abstract contextual information. Caregivers could also praise their children or offer corrections. Speech categories were mutually exclusive with the exceptions of praise and correction. Behavior management, other, and inaudible were coded to ensure that each utterance received a code, but these categories were not analyzed individually because they were not hypothesized to relate to learning.

The total number of mutually exclusive utterances across all speech categories (including behavior management, other, and inaudible) was summed to index *total speech*, reflecting the amount of speech the caregiver provided during teaching. The number of utterances within each speech category was also counted per toy (*step-by-step speech*, *goal speech*, *label speech*, *context speech*, *praise speech*, and *correction speech*). See [supplementary material](#) for details on defining and coding utterances, additional subcategories of speech coding, and coding of caregivers' gestures and physical guidance.

*Child contributions to teaching. Underlying abilities.* Child-level individual differences were operationalized by measuring children's performance on the control items at test (reflecting propensity to assemble objects), vocabulary (MCDI), and age. These variables could plausibly relate to learning because older children or those more likely to assemble objects could learn more from instruction, and vocabulary varies among young children. As mentioned previously, in addition to providing a measure of children's spontaneous discovery of target actions, *control test scores* indexed children's propensity to assemble toys into configurations without instruction (see "[Test coding](#)" section above). The *vocabulary* score was generated by counting the number of words caregivers reported that children said on the MCDI. Children's *age* in months was also calculated.

*Actions.* Children's target action performance during teaching could relate to learning because action performance reflects opportunities for children to practice the material to be learned. Child actions during teaching were coded in the same way as caregiver actions during teaching and child actions at test. The same measures were calculated for child actions as were calculated for caregiver actions; the total number of target actions children attempted across action types was summed for a measure of *child count of target actions*, and the different target action types children performed out of the total action types per toy was calculated as the *child proportion of target action types*. Children's highest scoring attempt of each action type was averaged for a measure of *child best performance score* and, analogous to caregiver best performance score, reflected children's action accuracy during teaching.

One additional measure indexed children's actions during teaching: To assess whether caregivers or children performed more target actions relative to one another, *child share of target actions* was

calculated by dividing the child count of target actions by the sum of the child and caregiver count of target actions. This measure captured the extent to which children “drove” teaching. For example, if a child performed 12 actions in total on the cat and the caregiver performed 4 actions, the child share of target actions would be .75 [ $12 / (12 + 4)$ ]. Greater child share of target actions reflected more child activity relative to the caregiver.

**Reliability coding.** A different coder blind to research hypotheses coded 7 of the 32 sessions (22%, including teaching and test) for reliability. Each teaching measure was calculated for each puzzle and block session separately for each dyad and compared between coders (e.g., the child count of target actions was calculated for each child’s puzzle teaching session and compared between coders). Test scores were calculated for each child on each toy, and scores were also compared between coders. Reliability between the new coder and the original coder on each variable was high. Reliability was measured with Cronbach’s alpha (average = .931, range = .756–.989) and intraclass correlation coefficient (ICC; Koo & Li, 2016) (average ICC = .924, range = .727–.988; average  $F = 27.19$ , range = 4.10–88.30; all  $ps < .01$ , range =  $p < .001$ –.008) (see [supplementary material](#) for details on each measure).

## Results

Data analysis addressed the following goals. First, we examined whether children learned more actions from instruction (taught test score) compared with actions children spontaneously performed without instruction (control test score). Second, we tested whether child-level factors (control test score, vocabulary, and age) related to learning. Third, we tested whether caregivers contributed to learning (measured by instructional time, caregiver actions, and caregiver speech). Fourth, we examined whether child contributions (child actions) related to learning. Fifth, we tested whether caregiver speech related to child actions during teaching.

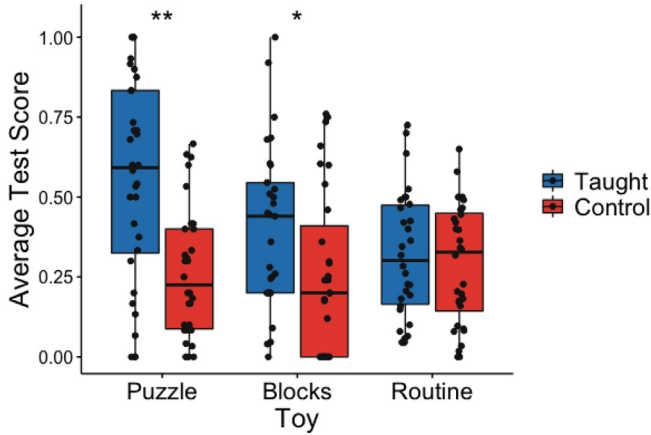
Linear mixed-effects models with participants as random effects were constructed to determine which variables related to children’s learning using the *lmer* function from the *lme4* package in R (Bates, Mächler, Bolker, & Walker, 2015). The  $p$  values were obtained using Satterthwaite approximation. Similar results were found if count variables were square root transformed and proportion data were arcsine square root transformed. Transformations were not applied because they did not improve model diagnostics. Relevant descriptive statistics are included in each section below; see [supplementary material](#) for additional details.

### Learning from instruction

Each child received a score on at least four of the six test toys. In total, children refused eight test toys, distributed across toy category and taught versus control. Across all taught and control items, the average test score was 0.35. Children’s scores did not differ by the type of item within each toy category (puzzles: cat vs. snowman; blocks: house vs. bridge; routines: fruit salad vs. sandwich; paired-samples  $t$  tests, all  $ps > .16$ ). Thus, further analyses were collapsed across items within each toy category.

Children scored higher on taught items than on control items,  $t(31) = 5.972$ ,  $p < .001$ , indicating that they performed more target actions with greater accuracy after receiving instruction than the actions they performed spontaneously without instruction. Specifically, children more accurately performed target actions on taught puzzles than on control puzzles,  $t(29) = 5.693$ ,  $p < .001$ ,  $d = 1.087$ , and blocks,  $t(27) = 3.101$ ,  $p = .004$ ,  $d = .538$ , but not routines,  $t(29) = 0.355$ ,  $p = .725$  (see [Fig. 1](#)). This suggested that children learned to perform target actions on puzzle and block toys through caregiver instruction.

Therefore, routine toys did not meet the criteria we set out for toys included in analyses; children spontaneously performed target actions without instruction, and instruction did not increase children’s target action performance. This was likely because children already had established scripted behaviors for pretend food toys. At test, most children performed typical pretend food actions; three quarters of children broke the fruit into pieces, and all but 3 children stacked sandwich pieces. In addition, some target actions were performative; few children “ate” the pretend food (fruit salad: 3



**Fig. 1.** Taught test score and control test score by toy category. Boxplots of average test scores for each toy category by taught and control items are shown. Dots represent individual participants. Higher scores on taught toys compared with control toys represent learning from instruction. \* $p < .05$ ; \*\* $p < .001$ .

children; sandwich: 2 children). The goal of the study was to understand which caregiver and child behaviors contributed to children learning to perform target actions. Because the routine toys did not meet our criteria, we did not analyze predictors of learning for routines. Additional analyses examined whether caregiver or child contributions to teaching related to learning (taught test scores) on puzzles and blocks.

### Child factors

Prior to examining which caregiver and child contributions to teaching related to taught test scores on puzzles and blocks, we explored relations between child-level individual differences (control test score, vocabulary, and age) and learning. In addition to measuring whether children discovered target actions independently, children’s control test scores reflected children’s propensity to construct toys without instruction. Children more prone to assemble objects may have learned more from instruction. Without instruction, children made scorable action attempts on control items but were variable in their performance; they performed on average 5.8 target actions (child count of target actions [test] range = 0–19) on control puzzles and blocks compared with 7.3 target actions (range = 0–21) on taught toys. Accuracy in action attempts was also variable; control test scores were on average 0.26 (range = 0–0.76). Higher control scores reflected children assembling toys into organized structures without instruction, which may relate to learning. As stated previously, children performed target actions with greater accuracy after receiving instruction (average taught test score = 0.47, range = 0–1) than without instruction. In addition to control test score, vocabulary is an interesting individual difference measure that varies among young children and could relate to learning. On average, children produced 45.9 words (range = 13–96). Older, more capable children might also learn more from instruction (average age = 23.4 months, range = 22.1–23.4).

Children’s control test scores, vocabulary, and age were analyzed as predictors of taught test score. Control test score ( $\beta = 0.378, SE = 0.153, p = .017$ ) and vocabulary ( $\beta = 0.004, SE = 0.002, p = .034$ ) were significant predictors of learning, whereas age was not ( $\beta = 0.039, SE = 0.034, p = .260$ ). Children with greater tendencies to assemble objects and larger vocabularies demonstrated better learning from instruction. Because construction propensity and vocabulary related to learning, control test scores and vocabulary were included in all additional models as covariates. This analysis strategy allowed us to examine which caregiver and child contributions to teaching, beyond children’s skills, related to learning.

## Caregiver contributions to learning

### Instructional time

Teaching for more time could allow children more exposure to the material to be learned. On average, caregivers instructed their children for 3.0 min per toy (instructional time range = 49 s to 6 min 35 s). However, instructional time was not a significant predictor of taught test score ( $\beta = -0.015$ ,  $SE = 0.026$ ,  $p = .560$ ), controlling for control test score and vocabulary. Therefore, we did not find evidence that teaching time related to learning, suggesting that teaching sessions including more exposure to the material to be learned did not relate to learning.

### Actions

Caregiver performances of target actions were demonstrations of the material to be learned, allowing children the opportunity to learn through observation. Caregivers performed on average 9.8 actions per toy (caregiver count of target actions range = 0–22), with at least 1 action on 63 of the 64 teaching sessions. Caregivers performed most of the different action types (average caregiver proportion of target action types = 0.81, range = 0–1). Caregiver actions were also accurate; caregiver best performance score was on average 0.86 (range = 0–1). Thus, caregivers were active during teaching, accurately performing most of the different action types. Caregivers also taught children all the target action types about twice per session (average number of complete action iterations = 1.8, range = 1–5).

Whereas the number of complete action iterations did not relate to learning ( $\beta = -0.002$ ,  $SE = 0.041$ ,  $p = .960$ ), more caregiver actions (caregiver count of target actions) *negatively* related to taught test score, controlling for control test score and vocabulary ( $\beta = -0.017$ ,  $SE = 0.007$ ,  $p = .025$ ) (see Fig. 2). Thus, caregivers who performed more actions had children who demonstrated poorer learning. We also controlled for this negative predictor to test whether learning was specifically reduced when caregivers performed more target action types (caregiver proportion of target action types) or performed target actions with greater accuracy (caregiver best performance score). Controlling for caregiver count of target actions, neither caregiver proportion of target action types ( $\beta = -0.211$ ,  $SE = 0.152$ ,  $p = .173$ ) nor caregiver best performance score ( $\beta = -0.151$ ,  $SE = 0.192$ ,  $p = .438$ ) related to children's learning. Contrary to predictions about the importance of viewing actions for learning, caregivers who performed more target actions during instruction had children who learned *less*.

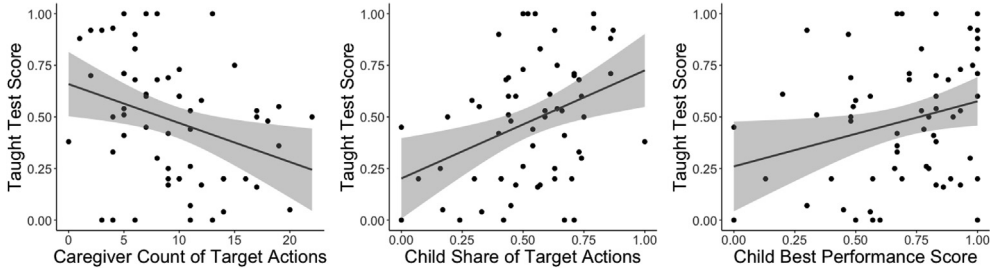
### Speech

Whereas caregiver action performance did not relate to learning, caregiver speech may have related to children's taught test scores. Caregivers on average spoke 42.9 utterances per session (total speech range = 12–83). However, total speech did not relate to taught test score ( $\beta = 0.001$ ,  $SE = 0.002$ ,  $p = .542$ ), controlling for control test score and vocabulary. We further analyzed each speech category to test whether particular types of speech related to learning. Of all speech categories, only step-by-step speech, the most common type of speech (37.3% of utterances), was marginally positively related to taught test score ( $\beta = 0.014$ ,  $SE = 0.008$ ,  $p = .061$ ), controlling for total speech, control test score, and vocabulary. There was no evidence that other speech categories related to learning (all  $ps > .12$ ). Thus, we did not find evidence for a direct relation between caregiver speech and child learning.

## Child contributions to learning

### Actions

When children performed more target actions during teaching, they may have learned through active experience and practice. Of the 64 teaching sessions, children performed or attempted at least one target action in 61 of the sessions, with an average of 11.6 actions per session (child count of target actions range = 0–31). Children performed most of the different action types during instruction (average child proportion of target action types = 0.80, range = 0–1). The balance of actions between caregiver and child (child share of target actions) averaged 0.53 (range = 0–1), and children's action accuracy (child best performance score) was on average 0.69 (range = 0–1). Overall, children were active and performed most of the different action types during teaching with relatively high accuracy. On average, children and caregivers were somewhat balanced in action performance relative to one another.



**Fig. 2.** Caregiver and child actions. Scatterplots of caregiver count of target actions (left), child share of target actions (middle), and child best performance score (right) graphed against taught test score are shown with linear trend lines and shaded 95% confidence intervals.

Neither child count of target actions ( $\beta = 0.001$ ,  $SE = 0.005$ ,  $p = .811$ ) nor child proportion of target action types ( $\beta = 0.089$ ,  $SE = 0.134$ ,  $p = 0.510$ ) related to learning, controlling for control test score and vocabulary. However, child share of target actions ( $\beta = 0.369$ ,  $SE = 0.173$ ,  $p = .039$ ) and child best performance score ( $\beta = 0.289$ ,  $SE = 0.136$ ,  $p = .039$ ) related to taught test score with the same controls (see Fig. 2). Children who were active relative to their caregivers and accurate in their actions learned more from instruction above and beyond children's vocabulary and propensity to assemble objects.

#### *Balance of caregiver and child actions*

The share of actions performed by children relative to caregivers related to learning, which raises questions about the balance of caregiver and child actions during instruction. Child share of target actions is by definition a trade-off between caregivers and children, but other metrics of caregiver and child action might not show such a trade-off. Both caregivers and children were active during teaching, but children performed significantly more actions than caregivers (child vs. caregiver count of target actions:  $\beta = 2.194$ ,  $SE = 1.011$ ,  $p = .033$ ). However, we did not find evidence that numbers of target actions performed by caregivers and children were related (child and caregiver count of target actions:  $\beta = 0.255$ ,  $SE = 0.178$ ,  $p = .158$ ).

In addition, even when controlling for children's actions, caregiver actions still negatively related to learning. Caregiver count of target actions remained a negative (marginal) predictor of learning ( $\beta = -0.016$ ,  $SE = 0.009$ ,  $p = .085$ ) when controlling for child share of target actions, control test score, and vocabulary. Similarly, caregiver count of target actions negatively related to learning ( $\beta = -0.016$ ,  $SE = 0.007$ ,  $p = .027$ ), and child best performance score positively related to learning ( $\beta = 0.275$ ,  $SE = 0.131$ ,  $p = .041$ ), controlling for control test score and vocabulary. Thus, whereas children were more active than caregivers and the numbers of actions performed by these agents were unrelated, fewer caregiver actions and greater child action accuracy independently related to children's learning.

It is also plausible that caregivers responded to their children's object assembly propensity (control test score) by adjusting the number of target actions they performed (e.g., by performing more target actions if their children were less likely to assemble objects). Yet, we did not see evidence for a relation between caregiver count of target actions and children's control test score ( $\beta = -0.006$ ,  $SE = 0.006$ ,  $p = .341$ ), controlling for vocabulary. Therefore, we did not find evidence that caregivers performed more actions for children who were less likely to construct toys.

#### *Caregiver contributions to child activity*

We did not see evidence that caregiver speech directly related to learning. Still, speech could have related to children's activity during teaching. In particular, we tested whether caregiver speech related to the two measures of child activity that related to learning: child share of target actions and child best performance score. Total speech did not relate to child share of target actions ( $\beta = 0.002$ ,  $SE = 0.001$ ,  $p = .150$ ) but did relate to child best performance score ( $\beta = 0.005$ ,  $SE = 0.002$ ,  $p = .002$ ), controlling for control test score and vocabulary. Both step-by-step speech and praise speech related

to child share of target actions ( $\beta = 0.013, SE = 0.005, p = .016$ , and  $\beta = 0.033, SE = 0.006, p < .001$ , respectively) and child best performance score ( $\beta = 0.014, SE = 0.006, p = .024$ , and  $\beta = 0.033, SE = 0.008, p < .001$ , respectively), controlling for control test score, vocabulary, and total speech. Thus, more speech overall related to more child actions relative to caregivers, and specific forms of speech (step-by-step speech and praise speech) related to greater child action accuracy during instruction.

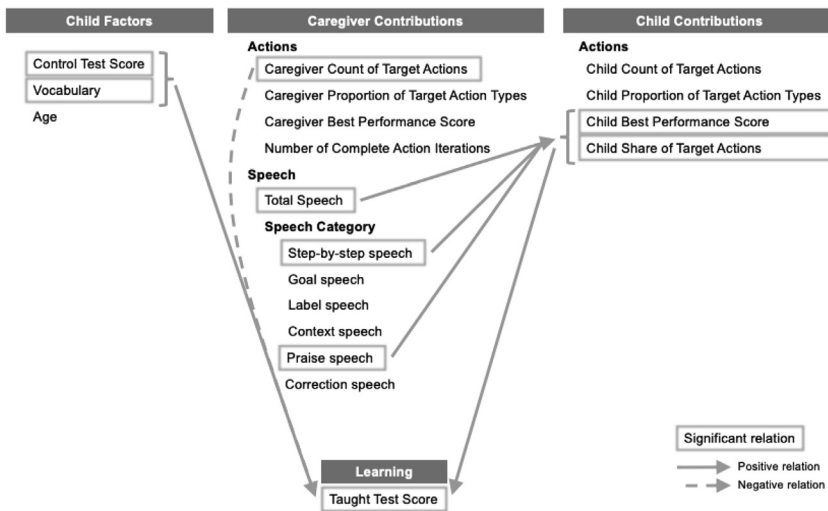
**Results summary**

The strongest predictor of children’s learning (taught test score) was children’s own action performance during teaching. Time spent teaching, caregiver target action performance, and caregiver speech did not relate to learning; in fact, when caregivers performed more actions, children evidenced less learning. Rather, children who were more active relative to their caregivers and more accurate in their actions demonstrated better learning. Importantly, caregivers supported children’s actions: More speech, specific instructions, and praise related to more child actions relative to caregivers and greater action accuracy during teaching. Therefore, caregivers may have played a role in children’s learning by supporting their actions (see Fig. 3).

**Discussion**

The current study examined a previously unstudied question: How do toddlers’ everyday interactions with caregivers support their learning of conventional actions on artifacts? Conventional action learning is an important developmental milestone through which children become competent users of culturally specific artifacts. Little is known about how everyday interactions with social partners, such as caregivers, support conventional action learning. The current study examined caregiver and child contributions to everyday interactions that supported toddlers’ learning of novel actions on artifacts. Importantly, we used a learning outcome to test which contributions to interactions related to children’s action learning.

Results demonstrated that children learned to perform target actions on two of three toys through caregiver instruction, as evidenced by higher test scores on taught items compared with control items.



**Fig. 3.** Results summary. Child factors and teaching measures (caregiver and child contributions) related to children’s learning (taught test score) are shown. Outlined measures represent significant relations. Solid arrows represent positive relations. Dashed line represents negative relation.



Learning was in part predicted by children's own competencies; children's propensity to assemble objects and vocabularies was associated with their learning. Despite the wealth of research on the benefits of adult instruction for learning, caregiver action performance and speech either did not relate or negatively related to children's learning. This was surprising because caregivers performed the actions to be learned with high accuracy and offered explicit verbal guidance about the taught material. Instead, children's own actions mattered for learning; the extent to which children drove the teaching session and performed actions accurately related to their learning. This was likely because children were practicing the actions their caregivers taught them to perform. Although caregiver strategies did not directly relate to learning, caregivers were instrumental in guiding children's activity. Children were more active and accurate in their actions when caregivers used more speech, particularly specific instructions and praise. Controlling for children's competence, children learned to perform novel actions on artifacts when they were active during instruction, supported by caregiver coaching. Thus, children were not active learners in isolation. Instead, a competent cultural expert guided children's activities, which in turn facilitated learning.

This study offers novel contributions to our understanding of how everyday instruction supports conventional action learning early in life. In contrast to language learning (Kuhl, 2007) and action imitation in the lab (Tomasello et al., 1993), adult action demonstration did not enhance learning. In fact, when caregivers provided action demonstrations for children, children actually evidenced less learning. Children were pivotal agents of their own action learning, in line with Piagetian ideas about the benefits of active experience (Piaget, 1964). However, culturally defined actions on artifacts might not be discoverable through independent activity alone; a cultural expert may be necessary to guide the actions of a novice (Tomasello, 1999; Vygotsky, 1980). In line with this research, we found that caregiver speech related to better child-independent activity. In particular, caregivers who offered specific action-relevant speech and praise had more active children. Additional coding of caregiver speech (see [supplementary material](#)) indicated that the majority of caregivers' action-relevant speech was instructions that promoted children's actions; thus, this speech likely preceded child activity. In contrast, praise often referred to actions, so praise likely occurred after child action as a reinforcement. In sum, active experience was crucial for learning, coached to accuracy by a knowledgeable social partner via instruction and reinforced with praise.

These results align with research in older children. For example, 3- to 6-year-olds learned more about the causal structure of a gear exhibit when caregiver talk was timed with children's active exploratory behavior (Callanan et al., 2020). Similar to the current study, caregiver speech did not relate to learning; indeed, some types of caregiver speech (e.g., directive speech) negatively predicted children's learning. Instead, children evidenced greater learning of gears' causal structure when caregivers talked to their children before they engaged in systematic exploration, which in turn predicted causal learning. This evidence suggests that caregiver-guided active experience may benefit learning throughout development in informal learning contexts.

There are at least two possible explanations for our results, namely that children learned well through active experience due to either (a) trait (stable) features of the children or caregiver-child dyad or (b) state (changing) features of the environment or task. The trait explanation would suggest that particular children tend to engage in active experience when learning and would do so across tasks, situations, and interaction partners. If the same children were tested again in new situations, they would likely engage in active learning. The trait explanation could also be specific to particular caregiver-child dyads; certain dyads may interact in a child-active style and do so across situations. If the same child were paired with a different partner, he or she might not engage in an active style. Alternatively, the state explanation would suggest that there is nothing particular to the children or dyads; certain situations or experiences may foster child-active styles despite enduring traits of the learners. By this explanation, children would engage in different types of learning strategies across situations, perhaps depending on children's interests, attention levels, prior knowledge, and/or abilities. Because we analyzed learning with two toys, we could not test whether children or dyads regularly engage in active learning styles across situations in a trait-like way or whether children or dyads shift between styles due to external factors in a state-like way. This is an interesting area for continued research.

### Questions for future research

This study raises important questions for future research. Although we found that guided child action related to learning, the directionality of this relation is unclear; it is unknown whether the caregiver or child initiated teaching strategies. Caregivers may have intentionally coached their children to be more active during instruction, or children may have elicited teaching strategies from caregivers that enhanced their own activity. Although we could not measure whether caregivers engaged in certain teaching styles intentionally, future experiments could examine the directionality of this relation.

The role of children's own skill in learning should also be examined further. One could argue that more capable children received more effective instruction; however, we controlled for children's propensity to assemble objects and vocabularies in all analyses. Despite child-level individual differences, active experience guided by caregiver speech related to learning, rendering this explanation unlikely. Similarly, caregiver action performance could have decreased learning if caregivers performed actions only when teaching unskilled children. However, we did not find a relation between caregiver action performance and child object construction propensity. Thus, the explanation that more able children received better instruction is unfounded. Still, children's skill could be examined in more detail in future studies. Here, we used control test scores as a proxy for children's object assembly propensity; yet, these scores could reflect motor skill, cognitive skill, or a combination. Future studies could examine which component of children's object-related skills specifically supports action learning.

In addition, caregivers were specifically told to teach their children to perform target actions using toys in a lab environment. Although this allowed for examination of a relatively restricted set of caregiver and child behaviors, observing dyads interact in their homes could yield additional insight into natural instruction. Importantly, we included a learning outcome measure that would be more difficult to implement in a home environment. Still, more naturalistic studies could be conducted to better understand how instruction proceeds in children's daily lives.

Of note, we tested action learning on a set of toys, which differ from other artifacts children learn about early in life (e.g., spoons). We developed items that would be familiar to caregivers and children, evoking a natural environment while introducing novel actions to be learned. It is possible that the interaction patterns seen here were specific to playful toy-based contexts and may differ from other situations with different conventions (e.g., using an eating utensil appropriately). Indeed, children did not demonstrate learning on the routine toys, suggesting that learning order-based tasks similar to those used in studies of deferred imitation (Barr, Dowden, & Hayne, 1996) may differ from the learning studied here. Because children's learning may differ in these contexts, future studies should examine whether similar interaction patterns benefit learning in situations with different goals.

It should be noted that these brief teaching sessions reflected only a sample of how dyads typically interact; it is unknown whether broader interaction styles featuring active experience relate to children's learning. General qualities of parenting benefit action learning; autonomy-oriented behavior and sensitive caregiving supported 12-month-olds' persistence, confidence, and affect when playing with new objects (Grolnick, Frodi, & Bridges, 1984), and caregivers who were modestly controlling, sensitive (Hohenberger et al., 2012), and emotionally available (Licata et al., 2014) had infants with better understanding of goal-directed actions. Whereas these global caregiving styles seem to be important for infant object engagement, the current study tested specific caregiver and child contributions to instruction that related to action learning. Still, future studies could address how overarching parenting styles affect children's learning.

Our findings indicate that active experience matters for U.S. children's conventional action learning, but this raises questions about contributions to this type of learning in other cultural contexts. Caregiver behaviors vary dramatically across cultures, and members of certain cultures may engage in less explicit child teaching. For example, Yucatec Mayan caregivers perform daily work without pedagogical intent (Gaskins & Paradise, 2010). Children are rarely directly taught; instead, they learn through observing others (Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo, 2003). Although we know how caregiver behaviors vary cross-culturally, we know less about how children's own actions may support their learning. Future studies could address whether and how children's active experience affects learning during the course of everyday activities across cultures.

In addition, learning to perform conventional actions on artifacts is a skill that can be considered as on a continuum of culture-specific learning domains children experience throughout development. From object learning during toddlerhood to math learning in school-aged children, there are many “cultural tools” children might not learn through independent experience alone, necessitating instruction from a cultural expert (Vygotsky, 1980). In line with math learning (DeCaro & Rittle-Johnson, 2012), children’s active experience combined with instruction supported action learning. Child-centered learning guided by an adult has been proposed to be beneficial in educational contexts; both “guided play” (Weisberg, Hirsh-Pasek, Golinkoff, Kittredge, & Klahr, 2016) and the Montessori method (Lillard, 2018) align with our results, suggesting that the current findings might apply more broadly to children of different ages learning a range of culturally defined information.

### Conclusion

This study examined how toddlers learn conventional actions during the course of everyday interactions with caregivers. This work represents an important first step in understanding the roles of the caregiver and the child in the learning process. Whereas prior literature points to the importance of caregiver demonstrations for information transfer, we found that children play a more central role in action learning than previously realized. Indeed, children’s own active experience with artifacts, and not viewing caregiver actions, enhanced learning. Caregivers supported learning through coaching children’s actions. This study sheds light on elements of social interactions that support action learning early in life, particularly highlighting the role of child activity supported by caregiver guidance.

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### Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jecp.2021.105201>.

### References

- Bandura, A. (1977). *Social learning theory*. New York: General Learning Press.
- Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24-month-old infants. *Infant Behavior and Development*, 19, 159–170.
- Barrett, T. M., Davis, E. F., & Needham, A. (2007). Learning about tools in infancy. *Developmental Psychology*, 43, 352–368.
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1). <https://doi.org/10.18637/jss.v067.i01>.
- Bates, E., Carlson-Luden, V., & Bretherton, I. (1980). Perceptual aspects of tool using in infancy. *Infant Behavior and Development*, 3, 127–140.
- Bauer, P. J. (1996). What do infants recall of their lives? Memory for specific events by one- to two-year-olds. *American Psychologist*, 51, 29–41.
- Bigelow, A. E., MacLean, K., & Proctor, J. (2004). The role of joint attention in the development of infants’ play with objects. *Developmental Science*, 7, 518–526.
- Bruner, J. S. (1972). Nature and uses of immaturity. *American Psychologist*, 27, 687–708.
- Callanan, M. A., Legare, C. H., Sobel, D. M., Jaeger, G. J., Letourneau, S., McHugh, S. R., ... Barnett, A. (2020). Exploration, explanation, and parent–child interaction in museums. *Monographs of the Society for Research in Child Development*, 85(1), 7–137.
- Carpenter, M., Akhtar, N., & Tomasello, M. (1998). Fourteen- to 18-month-old infants differentially imitate intentional and accidental actions. *Infant Behavior and Development*, 21, 315–330.

- Contaldo, A., Cola, E., Minichilli, F., Crecchi, A., Carboncini, M. C., Rossi, B., & Bonfiglio, L. (2013). Object use affects motor planning in infant prehension. *Human Movement Science, 32*, 498–510.
- Csibra, G., & Gergely, G. (2009). Natural pedagogy. *Trends in Cognitive Sciences, 13*, 148–153.
- Dean, D., & Kuhn, D. (2007). Direct instruction vs. discovery: The long view. *Science Education, 91*, 384–397.
- DeCaro, M. S., & Rittle-Johnson, B. (2012). Exploring mathematics problems prepares children to learn from instruction. *Journal of Experimental Child Psychology, 113*, 552–568.
- Eason, S. H., & Ramani, G. B. (2017). Parental guidance and children's executive function: Working memory and planning as moderators during joint problem-solving. *Infant and Child Development, 26*, 1–24.
- Elsner, B., Hauf, P., & Aschersleben, G. (2007). Imitating step by step: A detailed analysis of 9- to 15-month-olds' reproduction of a three-step action sequence. *Infant Behavior and Development, 30*, 325–335.
- Esseily, R., Rat-Fischer, L., O'Regan, K., & Fagard, J. (2013). Understanding the experimenter's intention improves 16-month-olds' observational learning of the use of a novel tool. *Cognitive Development, 28*, 1–9.
- Fagard, J., & Lockman, J. J. (2010). Change in imitation for object manipulation between 10 and 12 months of age. *Developmental Psychobiology, 52*, 90–99.
- Fenson, L., Pethick, S., Renda, C., Cox, J. L., Dale, P. S., & Reznick, J. S. (2000). Short-form versions of the MacArthur Communicative Development Inventories. *Applied Psycholinguistics, 21*, 95–115.
- Gaskins, S., & Paradise, R. (2010). Learning through observation in daily life. In D. F. Lancy, J. Bock, & S. Gaskins (Eds.), *The anthropology of learning in childhood* (pp. 85–117). Lanham, MD: Rowman & Littlefield.
- Gerson, S. A., & Woodward, A. L. (2014). Learning from their own actions: The unique effect of producing actions on infants' action understanding. *Child Development, 85*, 264–277.
- Grolnick, W., Frodi, A., & Bridges, L. (1984). Maternal control style and the mastery motivation of one-year-olds. *Infant Mental Health Journal, 5*, 72–82.
- Gunderson, E. A., Sorhagen, N. S., Gripshover, S. J., Dweck, C. S., Goldin-Meadow, S., & Levine, S. C. (2018). Parent praise to toddlers predicts fourth grade academic achievement via children's incremental mindsets. *Developmental Psychology, 54*, 397–409.
- Hohenberger, A., Elsabbagh, M., Serres, J., de Schoonen, S., Karmiloff-Smith, A., & Aschersleben, G. (2012). Understanding goal-directed human actions and physical causality: The role of mother–infant interaction. *Infant Behavior and Development, 35*, 898–911.
- Hunnus, S., & Bekkering, H. (2010). The early development of object knowledge: A study of infants' visual anticipations during action observation. *Developmental Psychology, 46*, 446–454.
- Hustedt, J. T., & Raver, C. C. (2002). Scaffolding in low-income mother–child dyads: Relations with joint attention and dynamic reciprocity. *International Journal of Behavioral Development, 26*, 113–119.
- Keen, R. (2011). The development of problem solving in young children: A critical cognitive skill. *Annual Review of Psychology, 62*, 1–21.
- Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine, 15*, 155–163.
- Kuhl, P. K. (2007). Cracking the speech code: How infants learn language. *Acoustical Science and Technology, 28*, 71–83.
- Legare, C. H. (2019). The development of cumulative cultural learning. *Annual Review of Developmental Psychology, 1*, 119–147.
- Licata, M., Paulus, M., Thoermer, C., Kristen, S., Woodward, A. L., & Sodian, B. (2014). Mother–infant interaction quality and infants' ability to encode actions as goal-directed. *Social Development, 23*, 340–356.
- Lillard, A. S. (2018). Rethinking education: Montessori's approach. *Current Directions in Psychological Science, 27*, 395–400.
- Luce, M. R., & Callanan, M. A. (2010). Parents' object labeling: Possible links to conventionality of word meaning? *First Language, 30*, 270–286.
- Luo, R., & Tamis-LeMonda, C. S. (2016). Mothers' verbal and nonverbal strategies in relation to infants' object-directed actions in real time and across the first three years in ethnically diverse families. *Infancy, 21*, 65–89.
- Mangold International. (2017). INTERACT user guide. Bavaria, Germany: Author. <https://www.mangold-international.com>.
- Meltzoff, A. N. (1988). Infant imitation and memory: Nine-month-olds in immediate and deferred tests. *Child Development, 59*, 217–225.
- Mermelshstine, R., & Barnes, J. (2016). Maternal responsive-didactic caregiving in play interactions with 10-month-olds and cognitive development at 18 months. *Infant and Child Development, 25*, 296–316.
- Needham, A., Barrett, T., & Peterman, K. (2002). A pick-me-up for infants' exploratory skills: Early simulated experiences reaching for objects using "sticky mittens" enhances young infants' object exploration skills. *Infant Behavior and Development, 25*, 279–295.
- Piaget, J. (1964). Piaget rediscovered: A report on the Conference on Cognitive Studies and Curriculum Development. In R. E. Ripple & V. N. Rockcastle (Eds.), *A report of the Jean Piaget Conferences at Cornell University and the University of California* (pp. 7–20). Ithaca, NY: Cornell University.
- Poulin-Dubois, D., Brooker, I., & Polonia, A. (2011). Infants prefer to imitate a reliable person. *Infant Behavior and Development, 34*, 303–309.
- Rat-Fischer, L., O'Regan, J. K., & Fagard, J. (2012). The emergence of tool use during the second year of life. *Journal of Experimental Child Psychology, 113*, 440–446.
- Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press.
- Rogoff, B., Paradise, R., Arauz, R. M., Correa-Chávez, M., & Angelillo, C. (2003). Firsthand learning through intent participation. *Annual Review of Psychology, 54*, 175–203.
- Shneidman, L., & Woodward, A. L. (2015). Are child-directed interactions the cradle of social learning?. *Psychological Bulletin, 142*, 1–17.
- Sobel, D. M., & Sommerville, J. A. (2010). The importance of discovery in children's causal learning from interventions. *Frontiers in Psychology, 1*. <https://doi.org/10.3389/fpsyg.2010.00176>.
- Sommerville, J. A., & Hammond, A. J. (2007). Treating another's actions as one's own: Children's memory of and learning from joint activity. *Developmental Psychology, 43*, 1003–1018.

- Soska, K. C., Adolph, K. E., & Johnson, S. P. (2010). Systems in development: Motor skill acquisition facilitates three-dimensional object completion. *Developmental Psychology, 46*, 129–138.
- Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.
- Tomasello, M. (2001). Cultural transmission: A view from chimpanzees and human infants. *Journal of Cross-Cultural Psychology, 32*, 135–146.
- Tomasello, M., Kruger, A. C., & Ratner, H. H. (1993). Cultural learning. *Behavioral and Brain Sciences, 16*, 514–515.
- van Schaik, J. E., Meyer, M., van Ham, C. R., & Hunnius, S. (2020). Motion tracking of parents' infant- versus adult-directed actions reveals general and action-specific modulations. *Developmental Science, 23* e12869.
- Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
- Weisberg, D. S., Hirsh-Pasek, K., Golinkoff, R. M., Kittredge, A. K., & Klahr, D. (2016). Guided play. *Current Directions in Psychological Science, 25*, 177–182.
- Williamson, R. A., & Brand, R. J. (2014). Child-directed action promotes 2-year-olds' imitation. *Journal of Experimental Child Psychology, 118*, 119–126.
- Winsler, A. (1998). Parent-child interaction and private speech in boys with ADHD. *Applied Developmental Science, 2*, 17–39.
- Winsler, A., Diaz, R. M., McCarthy, E. M., Atencio, D. J., & Chabay, L. A. (1999). Mother-child interaction, private speech, and task performance in preschool children with behavior problems. *Journal of Child Psychology and Psychiatry, 40*, 891–904.
- Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*, 89–100.
- Yuniarto, L. S., Gerson, S. A., & Seed, A. M. (2020). Better all by myself: Gaining personal experience, not watching others, improves 3-year-olds' performance in a causal trap task. *Journal of Experimental Child Psychology, 194* 104792.