Received: 23 February 2023 | Revised: 27 September 2023 | Accepted: 9 October 2023

DOI: 10.1002/dev.22435

RESEARCH ARTICLE

Developmental Psychobiology WILEY

How mothers help children learn to use everyday objects

Brianna E. Kaplan[1] | Isabella Kasaba[1] | Jaya Rachwani[2] | Karen E. Adolph[1] | Catherine S. Tamis-LeMonda[3]

[1]Department of Psychology, New York University, New York, New York, USA

[2]Department of Physical Therapy, Hunter College, City University of New York, New York, New York, USA

[3]Department of Applied Psychology, New York University, New York, New York, USA

Correspondence
Catherine S. Tamis-LeMonda, Department of Applied Psychology, New York University, Room 408 W, 246 Greene Street, New York, NY 10003, USA. Email: Catherine.tamis-lemonda@nyu.edu

Funding information
National Institute of Child Health and Human Development, Grant/Award Number: R01-HD086034; Defense Advanced Research Projects Agency, Grant/Award Number: N66001-19-2-4035

Abstract

Children must learn specific motor actions to use everyday objects as their designers intended. However, designed actions are not obvious to children and often are difficult to implement. Children must know what actions to do *and* how to execute them. Previous work identified a protracted developmental progression in learning designed actions—from nondesigned exploratory actions, to display of the designed action, to successful implementation. Presumably, caregivers can help children to overcome the challenges in discovering and implementing designed actions. Mothers of 12-, 18- to 24-, and 30- to 36-month-olds ($N = 74$) were asked to teach their children to open containers with twist-off or pull-off lids. Mothers' manual and verbal input aligned with the developmental progression and with children's actions in the moment, pointing to the role of attuned social information in helping children learn to use objects for activities of daily living. However, mothers sometimes "overhelped" by implementing designed actions for children instead of getting children to do it themselves, highlighting the challenges of teaching novices difficult motor actions.

KEYWORDS
affordances, cultural artifacts, designed actions, manual actions, social learning

1 | INTRODUCTION

Activities of daily living—such as dressing, grooming, and eating—involve objects with specific designed actions. For example, dressing requires buttoning shirts, zipping coats, tying shoes, and so on—skills children are expected to acquire by school age (Kellegrew, 1998). But learning the designed actions of everyday objects is difficult because often the affordances are hidden and must be discovered (Albrechtsen et al., 2001; Gaver, 1991; Hartson, 2003; Norman, 1999, 2002). Salient visual information (e.g., a brightly colored lid) may inform children about where to act, and available perceptual feedback from exploratory actions (e.g., lid twists when touched) may keep children in the appropriate location and hint at the correct action. But often such cues are unavailable (e.g., stuck lid) or unreliable (e.g., wiggly zipper tab). Additionally, implementation of designed actions often entails difficult perceptual–motor requirements. A zipper tab must be pulled opposite to the force of the stabilizing hand and approximately parallel to the zipper teeth (Rachwani, Kaplan, et al., 2020). A twist-off lid requires lifting and replacing one hand to twist continuously to the left while stabilizing the base with the other hand (Rachwani, Tamis-LeMonda, et al., 2020). Thus, children struggle to discover and implement the designed actions required to use the objects of daily living (Kaplan et al., 2022; Rachwani, Kaplan, et al., 2020; Rachwani, Tamis-LeMonda, et al., 2020).

Discovery and implementation are especially challenging for novice infants who lack top-down knowledge about what to do with a new object. Fortunately, learning is not a solitary endeavor. Before children independently perform the activities of daily living, they have repeated exposures to what objects can do and how to use them. Caregivers are cultural experts who can scaffold children's learning by demonstrating, verbally instructing, or simplifying the task. Indeed, the invention of complex objects and tools is expedited through cultural transmission of prior use cases, so new generations do not need to reinvent the wheel (Legare, 2019). Nonetheless, despite the likely importance of caregiver input for teaching children the activities of daily living (Kellegrew, 1998, 2000), little is known about how caregivers facilitate children's learning of designed actions on artifacts.

1.1 | Learning the designed actions of everyday objects

Claims about children's learning of designed actions are riddled with untested assumptions. Researchers assume that learning involves "trial-and-error" (Sewell et al., 1998) or extensive practice (Guidetti & Soderback, 2001), but little empirical data support these conjectures. The dominant approach to understanding children's use of everyday objects is to document the ages at which children successfully open containers, use buttons, zip clothing, and so on (Teaford, 2010). However, age norms do not inform on the processes for discovering and implementing such actions. In contrast, detailed behavioral coding reveals a developmental progression in children's learning of the designed actions of everyday objects (Kaplan et al., 2022; Rachwani, Kaplan, et al., 2020; Rachwani, Tamis-LeMonda, et al., 2020)—from nondesigned exploratory actions at 12 months (e.g., banging and shaking containers), to the basics of the designed action at 18–24 months (e.g., twisting the lid back and forth), to successful implementation by 30–36 months (e.g., stabilizing the base of the container with one hand while lifting and replacing the other hand to twist the lid continuously to the left). And although the steps of the progression hold across objects, the precise developmental timing depends on the transparency of the designed action, the availability of perceptual feedback, and the perceptual–motor requirements for each object–action system (Kaplan et al., 2022; Rachwani, Kaplan, et al., 2020; Rachwani, Tamis-LeMonda, et al., 2020).

1.2 | The social context of learning

Learning is socially embedded. However, most work on social learning—how caregivers scaffold the emergence of new skills—emphasizes cognitive skills such as word learning (Suanda et al., 2016; Suarez-Rivera et al., 2022). Caregivers point to objects while naming them, respond contingently to the objects in infants' hands, and infuse language into everyday routines in ways that help infants map word to world. But although social learning is often studied in the context of caregiver–child object play, researchers tend to ignore the specific strategies that caregivers use to scaffold children's learning of the designed actions of objects.

A handful of studies indicate that caregivers modify their manual actions in ways that help infants maintain attention and segment action sequences. For example, when caregivers demonstrate overt object actions to infants (e.g., manipulating a bendable ring), they engage in "motionese"—using slower and more exaggerated movements than when demonstrating the same actions to adults (Brand et al., 2007). And mothers modify action characteristics in real time in response to children's object manipulation (Fukuyama et al., 2015). But what strategies do caregivers use to facilitate children's learning of the designed actions of everyday objects? How do they help children surmount the challenges of discovering and implementing multistep, motorically difficult hidden affordances?

1.2.1 | Type and modality of social input

Learning designed actions is not easy. Children must be attentive to and interested in the task; know where to act, what to do, and how to do it; and ultimately have the biomechanical skills and strength to implement the action. As such, caregivers may draw on a variety of strategies to teach their children how to use everyday objects. Caregivers may direct children's *attention* to the task or *encourage* children to try on their own. Caregivers may offer critical *information about the affordance*—where to act, what the designed action is, and how to implement it. And they may *simplify the task* if the perceptual–motor requirements are beyond children's abilities.

Moreover, caregivers may differentially rely on manual and verbal input to convey information. Because implementing designed actions is inherently a motor task, manual input (e.g., demonstration on the object, gestures) provides visual cues about the basics of the action (e.g., rotational wrist movement). Concurrent verbal input can serve to reinforce the manual message. If caregivers say "twist, twist, twist" while demonstrating how to twist a lid, children both see and hear what to do. Alternatively, caregivers may use the two modalities in different but complimentary ways (e.g., verbally directing children's attention to a manual demonstration).

1.2.2 | Input across development and in real time

Effective teaching requires the input to be tailored to the developmental skills and moment-to-moment needs of the learner. For example, instructing a 12-month-old to "twist continuously to the left" is useless, just as guiding the hands of an expert 36-month-old is unnecessary. For help to be maximally effective, it should match the developmental progression in discovery and implementation. And in real time, the ebb and flow of inputs should align with what children do in the moment (Yu & Smith, 2013). An 18-month-old who simply touches a container may benefit from information about the designed action, whereas an 18-month-old who knows what to do but struggles may need help with implementation. Moreover, children's motor actions are readily observable: Caregivers can see in the moment exactly what children can do. Thus, differences in caregivers' input across children's development may reflect caregivers' responses to children's real-time behavior.

1.3 | Current study

We examined mothers' behaviors as they helped their 12-, 18- to 24-, or 30- to 36-month-old children discover and implement the designed actions of containers. The three age groups correspond to the stages of the developmental progression in prior work (exploration, designed action, successful implementation). We asked mothers to "teach their children to open containers" with twist-off or pull-off lids to retrieve a snack inside and examined mothers' input at different time scales (across child age and in the moment). Mothers were from a relatively homogenous sample (educated, middle to high socioeconomic status, English-speaking families in New York City) and appeared to be comfortable with the request to teach their children in a laboratory setting.

How does mothers' input change across *developmental time*? We hypothesized that the type and modality of mothers' input align with where they believe their children are along the developmental progression. We expected mothers of 12-month-olds to call on the full range of strategies to teach their novice babies how to open containers. We expected mothers to verbally orient children to the task, manually provide information about the affordance (i.e., location of the action, designed action, and specifics of implementation), and simplify the task by reducing the perceptual–motor requirements (i.e., stabilizing the base or partially opening the lid). In contrast, 18- to 24-month-olds have greater motor skills, vocabulary, and knowledge about the basics of the designed action, but struggle with implementation. Thus, we expected mothers to provide verbal and manual information about the affordance, but to verbally encourage children to implement the action rather than simplify the task. We expected mothers of skilled 30- to 36-month-olds to provide little input overall to their children who know the designed action and can implement it. Contrary to our predictions, it was possible that all types of input decrease with children's age, with mothers of more skilled children granting them greater autonomy to execute the task.

Second, we asked whether and how mothers' input changes in *real time* in response to children's actions. Presumably, age-related differences among mothers are the product of moment-to-moment responses to children's behaviors. For example, mothers might provide more input (e.g., information about the designed action) when children simply touch the container, but less input when children attempt the designed action, regardless of children's age. However, contrary to our expectations, age may be the driving force, with children's actions in the moment showing little influence on mothers' behaviors.

We expected differences in mothers' input by child age and real-time actions to generalize across containers with different designed actions (twist-off lids, pull-off lids) because the developmental progression is robust across objects (Kaplan et al., 2022; Rachwani, Kaplan, et al., 2020; Rachwani, Tamis-LeMonda, et al., 2020). Nonetheless, we ran supplementary analyses by container type.

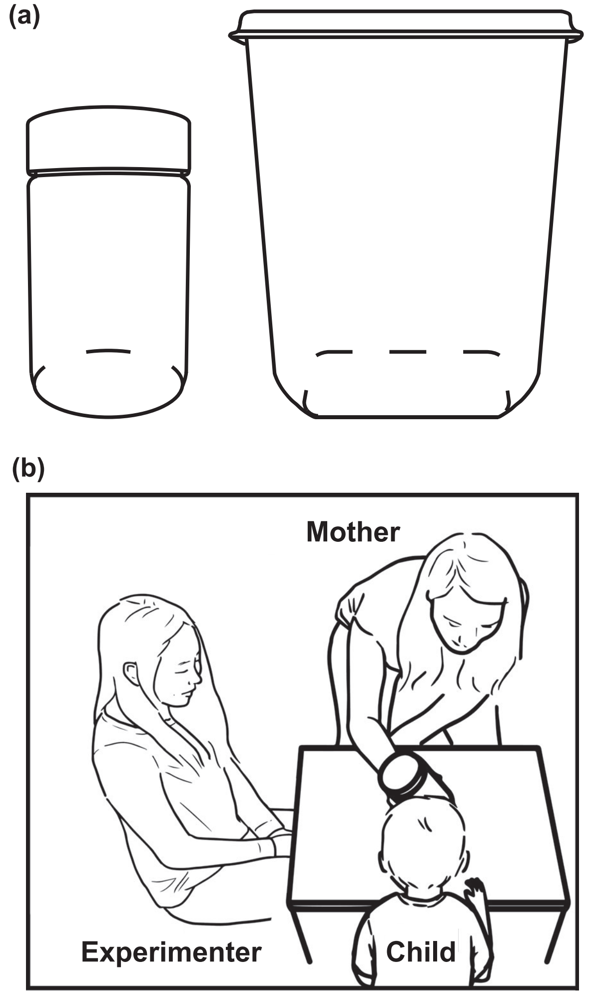

FIGURE 1 Test containers and method. (a) One of the 10 containers with twist-off lids and seven containers with pull-off lids. Twist-off size varied from 3.5 to 9.3 cm in diameter and 1.7 to 12.7 cm in height and pull-off size varied from 8.6 to 15.8 cm in width, 10.6 to 23.6 cm in length, and 4.1 to 10.1 cm in height. (b) Experimental setup.

2 | METHODS

2.1 | Data sharing on Databrary

With participants' permission, videos from each session and coding spreadsheets are openly shared with authorized investigators on Databrary (https://nyu.databrary.org/volume/1567). An exemplar video of the procedure, camera views, and behaviors of a typical mother and 18-month-old is publicly available at https://nyu.databrary.org/volume/1567/slot/64104. The coding manual (https://nyu.databrary.org/volume/1567/slot/63994), coding scripts (https://nyu.databrary.org/volume/1567/slot/63996), processed data (https://nyu.databrary.org/volume/1567/slot/63997), and analysis scripts (https://nyu.databrary.org/volume/1567/slot/63995) are also publicly shared on Databrary.

2.2 | Participants

We recruited sixteen 12-month-old children (eight boys, eight girls), thirty-one 18- to 24-month-old children (16 boys, 15 girls), and twenty-seven 30- to 36-month-old children (18 boys, nine girls) and their mothers from the New York City area (Figure 1a). Mothers reported children's race as White (65%), Black (3%), Asian (11%), multi-race (18%), or choosing not to respond (4%), and children's ethnicity as non-Hispanic (87%), Hispanic (12%), or choosing not to respond (1%). All children were healthy and born at term. Most mothers were from a middle-class background with at least 4 years of college. All study procedures were approved by the Committee on Activities Involving Human Subjects at New York University and caregivers consented to participation prior to inclusion in the study. Families received a tote bag and photo magnet as souvenirs of participation. Data from 11 additional dyads were excluded due to fussiness ($n = 4$), noncompliant mother behavior ($n = 3$), or experimenter error ($n = 4$).

2.3 | Containers

All containers were commercially available and had an opaque lid and a transparent base so children could see the treat inside (piece of dry cereal or cracker). Ten cylindrical twist-off containers had lids that required twisting continuously to the left to open and seven rectangular pull-off containers required stabilizing the base and pulling the edge of the lid to open (Figure 1a). To ensure that twist-off containers required the same number of turns to open across children, each lid and base were marked and aligned before each trial. Twist-off size varied from 3.5 to 9.3 cm in diameter and 1.7 to 12.7 cm in height and pull-off size varied from 8.6 to 15.8 cm in width, 10.6 to 23.6 cm in length, and 4.1 to 10.1 cm in height.

A transparent sugar bowl with an inverted lid served as the "warm-up" container to keep children motivated. Children could easily open the sugar bowl by grasping and lifting the lid to retrieve the treat inside.

2.4 | Procedure

Dyads were quasi-randomly assigned to the twist-off ($n = 36$) or pull-off condition ($n = 38$), to keep approximately equal numbers of children in each condition by age and sex. Children 24 months and younger sat in a high chair with a tray and children older than 24 months sat at a child-sized table. Mothers sat across from their children and an experimenter sat to the side (Figure 1b). An assistant sat behind mothers (out of children's view) to hand mothers the container at the start of each trial.

To acclimate children to the task, the experimenter first presented children with the warm-up sugar bowl. All children opened the sugar bowl twice before mother-led trials. Then, the experimenter instructed mothers to "teach your child to open each container as you normally would at home." Trials began when mothers first touched the container and ended when children opened the container (with or without assistance) or after 30 s, whichever occurred first. Containers were presented in random order, with the rule that two containers in the same size group could not be presented simultaneously. The experimenter ended the session early for three children who became too fussy to continue (17–25 months), so two dyads in the final sample received six trials and one received five trials. To ensure that mothers' and children's faces and hands were visible, one camera recorded a front view of mothers and two cameras recorded side views of children. Videos were mixed online into a single frame for later coding.

2.5 | Behavioral coding

A "bulk coder" annotated the videos frame-by-frame using Datavyu (www.datavyu.org) to time-lock user-defined events to their locations in the video. The coder focused on mothers' manual and verbal teaching behaviors and children's display of the designed twisting or pulling action and successful implementation (i.e., opening the container). Output from Datavyu yields the frequency and duration of each behavior and temporal contingencies between mother and child behaviors.

To test interobserver reliability, a second "spot checker" independently coded at least three randomly selected trials from each dyad (43% of each dyad's data), with a new random selection for each coding pass. We conducted reliability on a subset of trials from each dyad, rather than from a subsample of dyads, to prevent bias in agreement estimates by ensuring that mother- or child-specific behaviors were quasi-randomly distributed across dyads and time. Across behaviors, coders agreed on ≥96% of frames (and every action occurring in those frames); Cohen's $\kappa \geq .83$, $ps < .001$. Every few dyads, the bulk coder and spot checker reviewed disagreements to ensure their decisions did not drift from the rules in the coding manual. To prevent propagating known errors in the final dataset, the two coders resolved disagreements through discussion—using the correct annotation for typos and careless errors and the bulk coder's data for true disagreements.

2.5.1 | Mothers' manual behaviors

Coders noted three types of manual behaviors. *Attention* directives were rattling the container or pointing to the snack inside. Mothers provided *affordance* information by demonstrating the action with their hands on the container or with gestures, pointing to the lid of the container, showing proper placement of hands on the container without doing the designed action, or providing hands-on support (placing their hands on children's hands to facilitate part of the action). *Simplifying the task* referred to stabilizing the base of the container or partially opening the lid (as an intentional, discrete behavior or because mothers did not fully close the lid after a demonstration or hands-on support). Manual behaviors were mutually exclusive. Bouts began when the action started and ended when mothers changed the way the behavior was performed (e.g., gestured twisting with the whole hand then gestured twisting with just the finger), switched to a new behavior, or paused for >2 s between bouts of the same behavior.

2.5.2 | Mothers' verbal behaviors

Coders transcribed all videos for maternal speech at the utterance level. Utterances were defined as a unit of speech separated by grammatic closure or prolonged pause and onsets were coded for each utterance. Although utterances were time-locked to the video, they were scored as single-frame events at the start of the utterance in line with conventional transcription practices (https://www.play-project.org/coding.html#Transcription), and thus did not have a duration.

Coders then noted which utterances contained three types of information. *Attention* directives were attempts to direct children's attention to the task or to mothers' hands (e.g., "look," "watch me," saying the child's name, referencing the snack inside). *Encouragement* was prompting children to do the task (e.g., "now you try," "can you do it on your own?"). *Affordance* information was references to the designed action (e.g., "twist" or "pull"), what children should do with their hands (e.g., "use your finger"), the correct location to act (e.g., "from the top"), or specifics of implementation (e.g., "go all the same way"). Verbal behaviors were not mutually exclusive. For example, "watch me twist it" was coded as attention and affordance. The three content categories were referenced in 67% of mothers' utterances. In the remaining utterances, mothers provided feedback about children's current actions (e.g., "yes like that"), asked if they could help (e.g., "can I help you?"), referenced the container's size or difficulty (e.g., "it's a little one," "this one is harder"), compared the object to things the child had seen before (e.g., "like the last one," "like the peanut butter jar at home"), or provided "filler" utterances (e.g., "what do you think?"). Thus, on trials with none of the three content categories, mothers were not necessarily silent.

2.5.3 | Children's actions

Coders identified onsets and offsets of children *touching* the container and *displaying the designed action*. Touch bouts began at the first frame when the child touched the container and ended when the child's hands were off the container >2 s or at the first frame of a designed action bout. Designed action bouts began on the first frame when children started to twist or pull and ended after a >2-s pause. For twist-off lids, the designed action was defined as children using their palm and/or fingers on the top of or the side of the lid to rotate it and cause the lid to visibly move. For pull-off lids, the designed action was defined as children performing any pulling movement with their palm or pulling with their fingers under the lip of the lid. Coders also noted if the child *successfully opened* the container without mother simplifying the task.

2.5.4 | Coordination of mothers' manual and verbal behaviors

Multimodal input was temporal alignment within a 1-s window between the three types of manual input—attention, affordance information, and simplifying task—and the three types of verbal input—attention directives, encouragement, and affordance information. If multiple verbal behaviors were nested within a single manual behavior, each verbal behavior (with its temporally aligned manual behavior) was considered a separate multimodal event.

2.5.5 | Temporal alignment between children's real-time actions and mothers' responses

Mothers' manual and/or verbal behaviors were considered "responses" if they followed children's actions within a 3-s window. Only touch bouts that lasted at least 3 s were included (i.e., long enough for mothers to notice and respond to the action). Attempts at the designed action that were shorter than 3 s were included if the offset of the bout occurred before the trial ended.

2.6 | Data analysis

We used mixed model ANOVAs to analyze the frequency of manual and verbal input. We ran separate models for manual and verbal input because the subtypes did not fully overlap (i.e., simplify the task could only be manual and encourage only verbal). Children's age was a between-subject factor and input type a within-subject factor.

We used generalized estimating equations (GEEs) to test combinations of specific manual and verbal behaviors during multimodal input because mothers contributed different numbers of nested behaviors. Children's age was a between-subject factor and type of manual input and type of verbal input were within-subject factors. We used an identity link function and an exchangeable working correlation matrix to reflect the uniform correlations across behaviors within a dyad.

To examine mothers' responses to children's real-time behaviors, we compared mothers' manual and verbal responses to children's touch bouts versus their responses to children's attempts at the designed action. The outcome variable for each analysis was dichotomous (i.e., whether mother provided input for each child behavior) and thus we used binary logistic GEEs with a logistic link function and an exchangeable working correlation matrix for each age group.

Preliminary analyses showed no effects of sex, so sex was collapsed in further analyses. Differences by container type are reported when significant.

3 | RESULTS

Mothers drew on a variety of manual and verbal strategies to teach their children how to open containers. Aggregating across the 74 mothers, we coded 1261 manual and 2058 verbal behaviors. Verbal input was particularly prominent: Mothers verbally directed children's attention, encouraged children to open, or provided affordance information on most trials ($M = 87.26\%$, $SD = 19.59$). Manual input (attention, affordance, simplifying the task) was likewise high ($M = 74.13\%$ of trials, $SD = 35.44$), but less frequent than verbal input ($p < .001$). Mothers' manual actions were brief ($M = 1.50$ s, $SD = 1.16$), and duration did not change with children's age, $F(2) = 0.32$ $p = .73$.

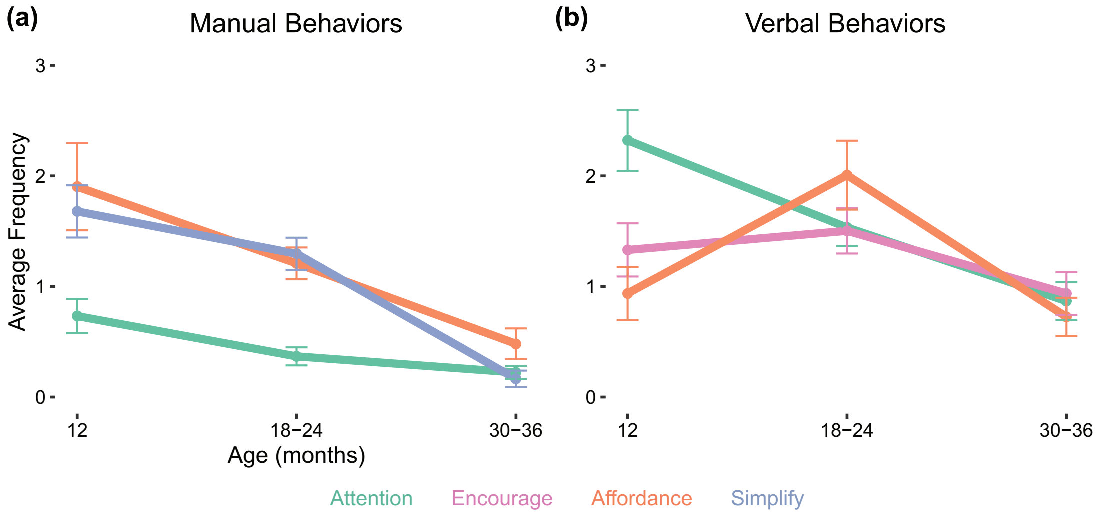

FIGURE 2 Mothers' manual and verbal behaviors across children's age. (a) Average frequency per trial of mothers' manual behaviors. (b) Average frequency per trial of mothers' verbal behaviors. Note the types of manual and verbal behavior only partially overlap. Note only attention and affordance inputs are included in both manual and verbal behaviors. Error bars represent standard error.

3.1 | Mothers modify their input in line with the developmental progression

Mothers' manual and verbal behaviors and multimodal input (i.e., temporal coordination between manual and verbal behaviors) differed with child age (behaviors: *Fs* > 4.16, *ps* < .001; coordination: Wald χ^2 = 394.78, *p* < .001). As hypothesized, different types of input showed different developmental patterns. Developmental patterns held across container type, *Fs* < 1.22, *ps* > .31, but mothers provided more manual and verbal affordance information for twist-offs than pull-offs regardless of children's age, *Fs* > 3.32, *ps* < .04.

3.1.1 | Input to 12-month-olds

Mothers of the youngest children called on the full suite of strategies to teach their children, in line with prior findings that 12-month-olds do not yet know the designed action of cultural artifacts (Rachwani, Tamis-LeMonda, et al., 2020). However, mothers' type of input differed by modality. Mothers relied primarily on manual actions to show children what to do and help them to do it and used verbal strategies to keep children on task.

Mothers' most common manual strategies were to provide information about the affordance and simplify the task (affordance: *M* = 2.07 per trial, *SD* = 1.61; simplify: *M* = 1.57 per trial, *SD* = 0.94; orange and blue lines in Figure 2a). In the context of their overall low frequency, attention directives (green line in Figure 2a; *M* = 0.73, *SD* = 0.62; *ps* < .001) were highest in mothers of 12-month-olds compared to the other two age groups, *ps* < .03.

Mothers' primary verbal strategy was to direct children's attention to the task (*M* = 2.32, *SD* = 1.10; green line in Figure 2b), and they did so more frequently than mothers of the two older age groups, *ps* < .03. Mothers also verbally encouraged their infants (pink line in Figure 2b; *M* = 1.33, *SD* = 0.96) and provided verbal affordance information (orange line in Figure 2b; *M* = 0.94, *SD* = 0.96) about once per trial.

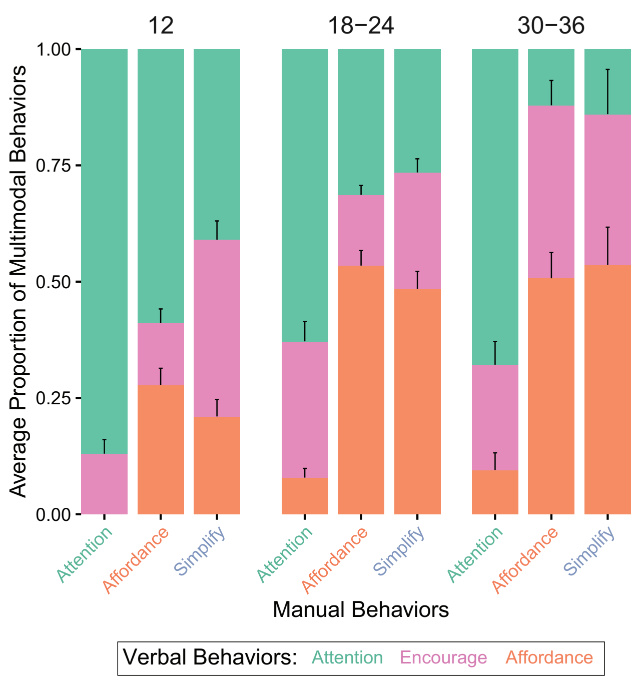

FIGURE 3 Proportion of each combination of mothers' manual and verbal behaviors during multimodal bouts across children's age. Error bars represent standard error.

When mothers provided multimodal input, most bouts contained verbal attention directives, mirroring the high overall frequency of this behavior. In instances when mothers' multimodal bouts incorporated manual attention directives, they reinforced the same message verbally (leftmost bar in Figure 3; *ps* < .001)—for example, by shaking the container while saying, "look over here." Thus, children could both see and hear what they should pay attention to. However, in instances when mothers' multimodal bouts included manual information about the affordance (second bar in Figure 3; *ps* < .02), they provided different yet complementary verbal information—for example, by demonstrating how to twist while verbally directing attention to the lid. Mothers' simplification of the task was equally likely to temporally correspond with all three verbal behaviors (third bar in Figure 3; *ps* > .14).

3.1.2 | Input to 18- to 24-month-olds

Mothers of 18- to 24-month-olds displayed behaviors that largely aligned with our predictions. Specifically, verbal references to the affordance peaked (orange line in Figure 2b; *M* = 2.01, *SD* = 1.73; *p* = .03), indicating a shift from verbal direction to verbal instruction. Also as expected, mothers of 18- to 24-month-olds continued to provide manual affordance information at high rates (equivalent to mothers of 12-month-olds shown by the orange line in Figure 2a; *M* = 1.40, *SD* = 0.92; *p* = .13). However, contrary to our predictions, mothers simplified the task at a similar rate to that of mothers of 12-month-olds (blue line in Figure 2a; *M* = 1.23, *SD* = 0.80; *p* = .37), rather than showing the predicted decrease. Mothers may have sought to help their struggling children implement the action because of the challenges to manually teaching the specifics of implementation.

Mothers of 18- to 24-month-olds displayed fewer manual and verbal attention directives (manual: *M* = 0.37, *SD* = 0.92; verbal: *M* = 1.53, *SD* = 0.93) relative to mothers of younger children, *ps* < .03, presumably in line with children's growing attention skills. Verbal encouragement did not change with children's age (*p* = 1.00; *M* = 1.50, *SD* = 1.14).

Mothers' increase in verbal affordance information was also reflected in their multimodal input. In instances when mothers' multimodal bouts included manual information about the affordance, mothers of 18- to 24-month-olds were more likely to reinforce that input with verbal information about the affordance than were mothers of 12-month-olds (second bar in the middle section of Figure 3; *p* = .006)—such as demonstrating how to twist while saying, "twist, twist, twist." The same was true for multimodal bouts that included simplification of the task (third bar in the middle section of Figure 3; *p* = .007). Mothers accomplished one part of the problem for children and verbally let them know which part to attempt next (e.g., stabilizing the base of the container for the child and saying "Now pull it"). However, when mothers' multimodal bouts included manual attention directives, mothers were still most likely to reinforce the information with verbal attention directives (first bar in the middle section of Figure 3; *ps* < .04).

3.1.3 | Input to 30- to 36-month-olds

Mothers of the oldest children displayed fewer behaviors than mothers of 18- to 24-month-olds (see Table 1), as predicted. Exceptions were verbal encouragement and manual attention directives (already rare at 18–24 months), which did not differ from mothers of 18- to 24-month-olds (*ps* > .14; encouragement: *M* = 0.94, *SD* = 1.00; attention: *M* = 0.22, *SD* = 0.31). Still, mothers provided each type of verbal input once per trial, on average.

TABLE 1 Manual and verbal behaviors of mothers of 30- to 36-month-olds.

	M	*SD*
Manual		
Attention	0.22	0.31
Affordance	0.50	0.74
Simplify	0.14	0.34
Verbal		
Attention	0.86	0.88
Encourage	0.93	1.00
Affordance	0.72	0.90

Mothers' multimodal input was similar to that of mothers of 18- to 24-month-olds, *ps* > .25. However, mothers were more likely to pair manual information about the affordance with verbal encouragement than mothers of 18- to 24-month-olds (middle bar in rightmost section of Figure 3; *p* = .05).

3.1.4 | Specific affordance behaviors

Although we speculated that mothers may communicate affordance information differently based on child age (e.g., mothers of younger children may display more hands-on support and mothers of older children may gesture the designed action), they did not. Manually, mothers of 12- and 18- to 24-month-olds alike mostly demonstrated the designed action, *ps* < .004. Mothers of 30- to 36-month-olds rarely provided manual affordance information, and so did not differ in the specific types of input, *ps* > .18. Verbally, mothers of 18- to 24-month-olds mostly referenced the designed action (e.g., "twist it"), *ps* < .001. Verbal affordance information was relatively low at 12 and 30–36 months, so specific behaviors did not differ, *ps* > .22.

3.2 | Mothers modify their input in line with children's real-time actions

Mothers' real-time responses to children's actions provide a complementary lens on their input across development. Presumably, developmental changes in children's knowledge and skills are reflected in children's moment-to-moment behaviors—such as when a novice 12-month-old simply holds a container without attempting to open it, but a knowledgeable 24-month-old tries to twist. Children's real-time behaviors should play out in what mothers do (e.g., gesturing how to twist with the 12- but not 24-month-old).

To test real-time influences on mothers' input, we focused on mothers' manual and verbal behaviors that followed (within 3 s) children's

(a) touching the container and (b) attempting the designed action. Across age, children's bouts of touching decreased (30- to 36-month-olds touched less than the two younger age groups, *ps* $< .001$) and attempts at the designed actions increased (12-month-olds attempted less than the two older age groups, *ps* $< .02$). Twelve-month-olds were more likely to perform the designed action with pull-offs than with twist-offs, $p < .001$.

Overall real-time manual and verbal responses did not differ by container type, *ps* $> .18$. But like the developmental results above, mothers responded with more manual and verbal affordance information for twist-offs than pull-offs, $p < .03$, regardless of child action or age.

3.2.1 | Mothers attune manual input to children's real-time actions

Mothers' manual input depended on children's prior actions: When children simply touched the container, mothers joined in, but when children attempted the designed action, mothers pulled back, Wald $\chi^2(1) = 39.83$. Specifically, mothers were more likely to offer manual input following children's touch bouts than following children's attempts at the designed action (green bars in Figure 4a; $p < .001$). In addition, mothers of 30- to 36-month-olds provided less input than mothers of the two younger age groups, *ps* $< .002$, as indicated in post hoc analyses of the main effect for age, Wald $\chi^2(2) = 15.15$, $p = .001$.

Based on the times when mothers provided input (green bars in Figure 4a), we conducted separate GEEs on mothers' *type* of manual input by child action for each age group. Because 12-month-olds rarely attempted the designed action, and mothers' responses to attempts were likewise rare (19 times across the whole dataset), we only analyzed mothers' responses to children's attempts in the two older age groups. GEEs (based on the two older age groups) showed that the type of mothers' manual input did not depend on children's prior actions, Wald χ^2s < 1.07, *ps* $> .30$, but did differ by age group, Wald χ^2s > 19.10, *ps* $< .001$. Mothers of 12- and 18- to 24-month-olds were equally likely to provide affordance information as to simplify the task, regardless of children's prior action, *ps* $> .13$ (orange vs. blue bars in Figure 4b). In contrast, mothers of 30- to 36-month-olds were more likely to provide affordance information than to simplify the task, $p < .001$. Mothers of all three age groups rarely responded to their children's actions with manual attention directives (small green bars in Figure 4b).

3.2.2 | Mothers attune their verbal input to children's real-time actions

Mothers' verbal input paralleled real-time patterns for manual input, Wald χ^2s ≥ 8.09, *ps* $< .02$. Mothers were more likely to provide verbal input after children touched the container than after children displayed the designed action (see green bars in Figure 4c; $p < .001$), and they provided less input for 30- to 36-month-olds than for 18- to 24-month-olds, $p = 04$.

Moreover, separate GEEs on the type of verbal input mothers provided in response to children's actions differed by child action for mothers of the two older age groups, Wald χ^2s > 10.04, *ps* $\leq .007$ (as above, we did not further break down mothers' responses to 12-month-olds' designed action bouts due to the paucity of data). When children displayed the designed action, mothers of 18- to 24-month-olds and mothers of 30- to 36-month-olds privileged affordance information (orange bars in Figure 4d) over attention (green bars in Figure 4d; *ps* $\leq .002$) and mothers of 30- to 36-month-olds also privileged affordance information over encouragement (pink bars in Figure 4d; $p = .003$). However, when children of all ages touched the container, mothers offered all three forms of verbal input equally, *ps* $> .33$. An exception was that mothers' attention directives were lower for 30- to 36-month-olds, *ps* $\leq .001$.

4 | DISCUSSION

In contrast to nonspecifc actions such as reaching and walking that allow for a variety of solutions (McCollum et al., 1995; Snapp-Childs & Corbetta, 2009; Thelen et al., 1993), the activities of daily living require children to use objects with specific and hidden designed actions. Often, implementation of everyday objects is unforgiving: Successful implementation requires a specific action to be performed in a specific way. Thus, social input may be critical for learning what to do and how to do it. The benefits of social "scaffolding" for learning have been documented for cognition, language, and attention. However, we are the first to examine social scaffolding of manual actions on everyday objects—both in the moment and in relation to developmental change.

4.1 | Mothers' input across nested time scales

Mothers' verbal and manual input aligned with the developmental progression previously documented in children's actions on twist-off and pull-off containers, zippers, and Duplo bricks (Kaplan et al., 2022; Rachwani, Kaplan, et al., 2020; Rachwani, Tamis-LeMonda, et al., 2020). As hypothesized, mothers' helping behaviors showed distinct age-related patterns, rather than simply decreasing with child age. For infants who struggle to maintain attention on the task, have few words in their vocabulary, and possess limited motor skills, mothers verbally directed children's attention, manually showed them what to do, and helped them do it. For toddlers with more advanced language and motor skills, but who still struggle to implement the action, mothers supplemented manual supports with verbal information about the affordance. And for young children who could presumably succeed on their own, mothers let them work through the task with minimal support.

Developmental changes in mothers' input are likely driven in part by their responses to children's actions in the moment. Across development, children shifted from touching and exploring containers to

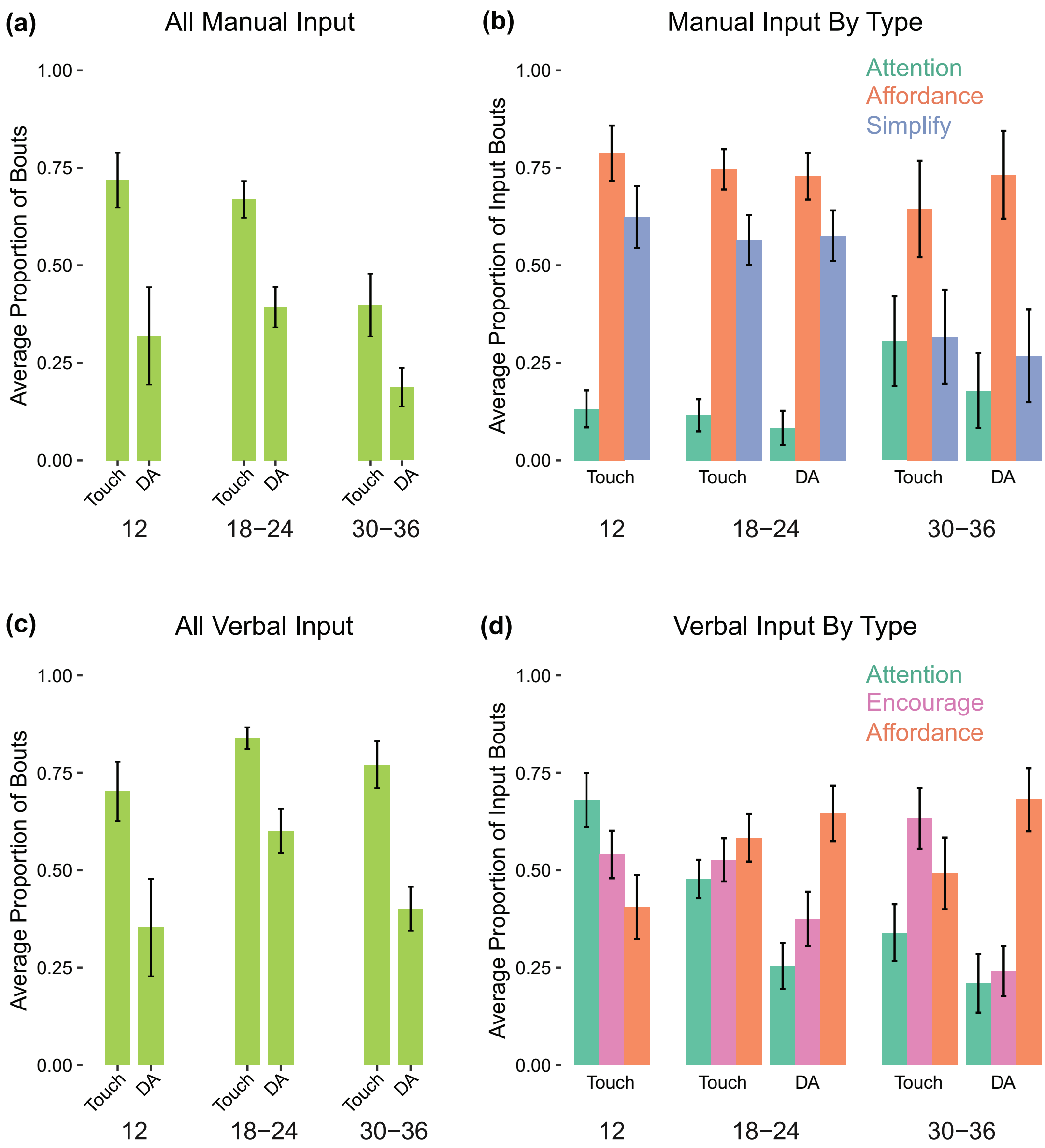

FIGURE 4 Mothers' real-time responses to children's actions. (a) Proportion of child action bouts (touch or designed action, DA) that mothers responded to with manual input within 3 s. (b) Proportion of manual input bouts by type. (c) Proportion of child action bouts (touch or designed action, DA) that mothers responded to with verbal input within 3 s. (d) Proportion of verbal input bouts by type. Note that mothers' responses to 12-month-olds' designed action attempts were not analyzed by type due to small frequencies. Error bars represent standard error.

attempting the designed action. And mothers' real-time responses changed accordingly. When children simply touched or explored the container, mothers quickly offered help, whereas when children attempted the designed action, mothers usually held back to allow their children to keep trying. However, in the occasional instances when mothers provided input following children's designed action attempts, they mostly provided information about the action and implementation. Of course, each child action cannot be separated from the history of other actions during the session. Thus, the amount and type of input that children receive may reflect the accumulation of their actions prior to that point in time.

Real-time behaviors are nested in developmental time. Accordingly, mothers' responses are necessarily the product of changes at both time scales. Children's developing motor and language skills likely influence the type of input that mothers provide in the moment and moderate the effectiveness of the input that children receive. For example, a 12-month-old and a 30-month-old who do not know a designed action will likely benefit from different types of input (e.g., the 12-month-old might require a demonstration, but the 30-month-old might benefit from mere verbal instruction). Thus, effective teaching requires attuning to children's actions in the moment in the context of children's broader skills.

4.2 | Teaching the specifics of implementation is hard

Although mothers' input generally aligned with the developmental progression reported in prior work, mothers sometimes simplified the task rather than teaching children how to overcome the perceptual–motor requirements of implementation. Unexpectedly, mothers of 12-month-olds and mothers of 18- to 24-month-olds were equally likely to simplify the task for their children. Similarly, in real time, mothers were just as likely to simplify the task when children attempted the designed action as when children only touched the container.

Simplifying the task may scaffold learning in 12-month-olds, who are unlikely to attempt the designed action independently. Although 12-month-olds have twisting and pulling in their repertoires, they have difficulty with bimanual coordination (i.e., simultaneously using one hand to open the container while the other stabilizes the base). By partially opening the lid or stabilizing the base, mothers helped channel infants' actions to one part of the problem, and thus supported infants' movement through the progression. Twelve-month-olds attempted the designed action more than did children in prior work who were the same age but independently tried to open the same containers without any input from mothers (Rachwani, Tamis-LeMonda, et al., 2020).

In contrast to the potential benefits of simplifying tasks for young infants, such "helping" behaviors may not be helpful for 18- to 24-month-old toddlers who possess the motor skills to accomplish the task but struggle with the specifics of implementation. However, mothers of toddlers did simplify the task, and this gambit may have backfired. Eighteen- to 24-month-olds were less successful than were same-aged children in previous work when attempting to open containers independently (Rachwani, Tamis-LeMonda, et al., 2020). Perhaps children would have eventually succeeded without mothers simplifying the task: Children of caregivers who less often manually intervened were more successful at a puzzle task than were children with caregivers who did more (Brezack et al., 2021).

Mothers may have simplified the task for their toddlers because teaching the specifics of implementation is difficult. The basics of twisting and pulling are likely easy to demonstrate. But, demonstrating the precise direction and amount of force of such actions is challenging, and mothers' hands may occlude critical information. Verbal input could potentially provide information about the details of the action (e.g., "turn to the left"), but in practice may simply function to direct children's attention.

Moreover, mothers' teaching strategies may be based on an egocentric perspective of how they typically open containers. For example, when mothers demonstrated opening, they used their hands to stabilize the base of pull-offs. In contrast, children sometimes stabilize the base of containers by holding the container against their chest, their forearm, or the table (Rachwani, Tamis-LeMonda, et al., 2020). Other strategies, such as hands-on guidance, may teach the specifics of implementation more effectively because children can feel exactly what needs to be done. But hands-on support was rare, and children sometimes pulled their hands out of mothers' grasp. Toddlers' quest for independence may prevent mothers from using certain types of teaching strategies (Zhang et al., 2021).

4.3 | Teaching and learning in the wild

What does social input for designed actions look like in everyday life? Mothers were instructed to teach their children to open containers, and their strategies may have differed from what they typically do during everyday routines and with other household objects. Mothers and other caregivers may take over dressing children, feeding them, and so on when rushing to get their children out the door. Still, "everyday demonstrations" over days, weeks, and months may add up to support children's learning about how to implement the activities of daily living. Nonetheless, children would need to observe other people's hands for the demonstration to be effective. Moreover, just as mothers' language input in the lab resembles the peaks of input at home (Tamis-LeMonda et al., 2017), mothers' input when they intentionally teach their children designed actions likely resembles the patterns we observed.

Documenting mothers' natural teaching strategies has implications for clinicians. Physical and occupational therapists know that social feedback supports children with motor delays (Kellegrew, 2000), but little evidence-based research exists on the type and timing of effective input. Given that all typically developing children eventually learn to use everyday objects, the strategies that mothers spontaneously adopt to support the activities of daily living may inform clinical practice.

Which types of input are effective for learning? A clear next step is to examine the effects of mothers' input on children's learning. Mothers' tailoring of input to children's actions and developmental level does not guarantee that children pick up on the relevant pieces of information. Perhaps complicated verbal guidance such as "twist to the left" simply functions as encouragement. And how far social input can go in the moment is limited. Social scaffolding may help children get farther than they would on their own (Vygotsky, 1978), but it is unlikely to overcome the limits of children's current motor, language, and cognitive skills. Moreover, the teaching that we observed in a relatively homogeneous sample (educated mothers of middle to high socioeconomic status) is not common everywhere. Caregivers in many cultures do not directly instruct their children (Shneidman et al., 2016); rather, children learn from observing caregivers' actions and joining in to help with everyday activities (Rogoff et al., 1993). Naturalistic data, across cultures and artifacts, are needed to reveal the everyday nature of caregivers' input.

5 | CONCLUSION

The world is full of cultural artifacts that children must learn to use as designed. But learning what to do and how to implement the required actions is difficult and follows a protracted developmental progression. Children are presumably beneficiaries of social input on a daily basis—as caregivers help zip up coats, open containers, and so on. But existing research ignores the social context of children's learning about object affordances. In contrast to treating children as "solitary scientists," we documented the behaviors that mothers use to teach their children how to open containers. Mothers displayed a rich variety of manual and verbal behaviors to elicit and engage child attention, provide affordance information, and simplify the task. Mothers' behaviors aligned with the developmental progression and children's moment-to-moment actions. Understanding the social factors that help children accomplish the activities of daily living can inform teaching protocols, shape clinical interventions, and guide the design of objects for children.

ACKNOWLEDGMENTS

This project was supported by NICHD grant number R01-HD086034 to K.E.A. and C.S.T. and by DARPA grant number N66001-19-2-4035 to K.E.A. We are grateful to David Comalli, Gladys Chan, Danielle Kellier, Justine Hoch, Carmen Zhang, Margaret Shilling, and Carli Heiman for help with data collection and coding.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

With participants' permission, videos from each session and coding spreadsheets are openly shared with authorized investigators in the Databrary digital library (https://nyu.databrary.org/volume/1567). An exemplar video of the procedure, camera views, and behaviors of a typical mother and 18-month-old, the coding manual, processed data, and analysis scripts are also publicly shared on Databrary.

ORCID

Brianna E. Kaplan https://orcid.org/0000-0002-6533-1885
Jaya Rachwani https://orcid.org/0000-0002-3756-8762
Karen E. Adolph https://orcid.org/0000-0003-2819-134X
Catherine S. Tamis-LeMonda https://orcid.org/0000-0002-9071-4028

REFERENCES

Albrechtsen, H., Andersen, H. H. K., Bodker, S., & Pejtersen, A. M. (2001). *Affordances in activity theory and cognitive systems engineering*. Riso National Laboratory.

Brand, R. J., Shallcross, W. L., Sabatos, M. G., & Massie, K. P. (2007). Fine-grained analysis of motionese: Eye gaze, object exchanges, and action units in infant-versus adult-directed action. *Infancy*, *11*, 203–214. https://doi.org/10.1111/j.1532-7078.2007.tb00223.x

Brezack, N., Radovanovic, M., & Woodward, A. L. (2021). Everyday interactions support toddlers' learning of conventional actions on artifacts. *Journal of Experimental Child Psychology*, *210*, 105201. https://doi.org/10.1016/j.jecp.2021.105201

Fukuyama, H., Qin, S., Kanakogi, Y., Nagai, Y., Asada, M., & Myowa-Yamakoshi, M. (2015). Infant's action skill dynamically modulates parental action demonstration in the dyadic interaction. *Developmental Science*, *18*, 1006–1013. https://doi.org/10.1111/desc.12270

Gaver, W. W. (1991). Technology affordances. In S. P. Robertson, G. Olson, & J. Olson (Eds.), *Proceedings of the CHI'91 SIGCHI Conference on Human Factors in Computing Systems* (pp. 79–84). ACM Press.

Guidetti, S., & Soderback, I. (2001). Description of self-care training in occupational therapy: Case studies of five Kenyan children with cerebral palsy. *Occupational Therapy International*, *8*, 34–48. https://doi.org/10.1002/oti.130

Hartson, H. R. (2003). Cognitive, physical, sensory, and functional affordances in interaction design. *Behavior and Information Technology*, *22*, 315–338. https://doi.org/10.1080/01449290310001592587

Kaplan, B. E., Rachwani, J., Tamis-LeMonda, C., & Adolph, K. E. (2022). The process of learning the designed actions of toys. *Journal of Experimental Child Psychology*, *221*, 105442. https://doi.org/10.1016/j.jecp.2022.105442

Kellegrew, D. H. (1998). Creating opportunities for occupation: An intervention to promote the self-care independence of young children with special needs. *The American Journal of Occupational Therapy*, *52*, 457–465. https://doi.org/10.5014/ajot.52.6.457

Kellegrew, D. H. (2000). Constructing daily routines: A qualitative examination of mothers with young children with disabilities. *American Journal of Occupational Therapy*, *54*, 252–259. https://doi.org/10.5014/ajot.54.3.252

Legare, C. H. (2019). The development of cumulative cultural learning. *Annual Review of Developmental Psychology*, *1*, 119–147. https://doi.org/10.1146/annurev-devpsych-121318-084848

McCollum, G., Holroyd, C., & Castelfranco, A. M. (1995). Forms of early walking. *Journal of Theoretical Biology*, *176*, 373–390. https://doi.org/10.1006/jtbi.1995.0206

Norman, D. A. (1999). Affordance, conventions, and design. *Interactions*, *6*, 38–43. https://doi.org/10.1145/301153.301168

Norman, D. A. (2002). *The design of everyday things*. Basic Books.

Rachwani, J., Kaplan, B. E., Tamis-LeMonda, C. S., & Adolph, K. E. (2020). Children's use of everyday artifacts: Learning the hidden affordance of zipping. *Developmental Psychobiology*, *63*(4), 793–799.

Rachwani, J., Tamis-LeMonda, C. S., Lockman, J. J., Karasik, L. B., & Adolph, K. E. (2020). Learning the designed actions of everyday objects. *Journal of Experimental Psychology: General*, *149*, 67–78. https://doi.org/10.1037/xge0000631

Rogoff, B., Mistry, J., Goncu, A., Mosier, C., Chavajay, P., & Brice, S. (1993). Guided participation in cultural activity by toddlers and caregivers. *Monographs of the Society for Research in Child Development*, *58*(8), v–vi, 1–174. discussion 175–179.

Sewell, T. J., Collins, B. C., Hemmeter, M. L., & Schuster, J. W. (1998). Using simultaneous prompting within an activity-based format to teach dressing skills to preschoolers with developmental delays. *Journal of Early Intervention*, *21*, 132–145. https://doi.org/10.1177/105381519802100206

Shneidman, L., Gaskins, S., & Woodward, A. (2016). Child-directed teaching and social learning at 18 months of age: Evidence from Yucatec Mayan and US infants. *Developmental Science*, *19*, 372–381. https://doi.org/10.1111/desc.12318

Snapp-Childs, W., & Corbetta, D. (2009). Evidence of early strategies in learning to walk. *Infancy*, *14*, 101–116. https://doi.org/10.1080/15250000802569835

Suanda, S. H., Smith, L. B., & Yu, C. (2016). The multisensory nature of verbal discourse in parent-toddler interactions. *Developmental Neuropsychology*, *41*, 324–341. https://doi.org/10.1080/87565641.2016.1256403

Suarez-Rivera, C., Linn, E., & Tamis-LeMonda, C. (2022). From play to language: Infants' actions on objects cascade to word learning. *Language Learning*, *72*, 1092–1127. https://doi.org/10.1111/lang.12512

Tamis-LeMonda, C. S., Kuchirko, Y., Luo, R., & Escobar, K. (2017). Power in methods: Language to infants in structured and naturalistic contexts. *Developmental Science*, *20*, e12456. https://doi.org/10.1111/desc.12456

Teaford, P. (Ed.). (2010). *HELP 2–6 Checklist* (2nd ed.). VORT Corporation.

Thelen, E., Corbetta, D., Kamm, K., Spencer, J. P., Schneider, K., & Zernicke, R. F. (1993). The transition to reaching: Mapping intention and intrinsic dynamics. *Child Development*, *64*, 1058–1098. https://doi.org/10.2307/1131327

Vygotsky, L. S. (1978). *Mind in society: The development of higher mental processes*. Harvard University Press.

Yu, C., & Smith, L. B. (2013). Joint attention without gaze following: Human infants and their parents coordinate visual attention to objects through eye-hand coordination. *PLoS ONE*, *8*, e79659. https://doi.org/10.1371/journal.pone.0079659

Zhang, Y., Wang, S. H., & Duh, S. (2021). Directive guidance as a cultural practice for learning by Chinese-heritage babies. *Human Development*, *65*, 121–138. https://doi.org/10.1159/000517081

How to cite this article: Kaplan, B. E., Kasaba, I., Rachwani, J., Adolph, K. E., & Tamis-LeMonda, C. S. (2023). How mothers help children learn to use everyday objects. *Developmental Psychobiology*, *65*, e22435. https://doi.org/10.1002/dev.22435