# 4-Month-Old Infants Individuate and Track Simple Tools Following Functional Demonstrations

Maayan Stavans

and

Renée Baillargeon

University of Illinois

**Please address correspondence to**:

Maayan Stavans
University of Illinois, Urbana-Champaign
Psychology Department
603 E. Daniel St.
Champaign, IL 61820
stavans2@illinois.edu

**Acknowledgments**

This research was supported by grants from NIEHS (P20 ES018163 and 1P01ES022848) and USEPA (RD83459301 and RD835434010). We thank Cindy Fisher for helpful comments, the staff of the University of Illinois Infant Cognition Laboratory for their help with the data collection, and the parents and infants who participated in the research.

4-Month-Old Infants Individuate and Track Simple Tools

Following Functional Demonstrations

**Research Highlights**

-We examined whether 4-month-olds could use categorical information to individuate and track objects.

-Infants first saw either functional or non-functional demonstrations for two different tools. Next, the tools were brought out alternately from behind a screen, which was then lowered to reveal only one of the tools. Infants who had seen functional demonstrations detected this violation, suggesting that they (a) assigned the two tools to distinct categories and (b) recruited these categorical encodings to individuate and track the tools.

-These results indicate that the privileged status of categorical information in individuation and identity tracking can be discerned from a very early age and as such constitutes a fundamental property of the cognitive architecture that supports these abilities.

YOUNG INFANTS INDIVIDUATE AND TRACK SIMPLE TOOLS

**Abstract**

Two experiments examined whether 4-month-olds (*n* = 120) who were induced to assign two objects to different categories would then be able to take advantage of these contrastive categorical encodings to individuate and track the objects. In each experiment, infants first watched functional demonstrations of two tools, a masher and tongs (Experiment 1) or a marker and a knife (Experiment 2). Next, half the infants saw the two tools brought out alternately from behind a screen, which was then lowered to reveal only one of the tools (different-objects condition); the other infants saw similar events except that the same tool was shown on either side of the screen (same-object condition). In both experiments, infants in the different-objects condition looked reliably longer than those in the same-object condition, and this effect was eliminated if the demonstrations involved similar but non-functional actions. Together, these results indicate that infants (a) were led by the functional demonstrations they observed to assign the two tools to distinct categories, (b) recruited these categorical encodings to individuate and track the tools, and hence (c) detected a violation in the different-objects condition when the screen was lowered to reveal only one tool. Categorical information thus plays a privileged role in individuation and identity tracking from a very young age.

Keywords: infant cognition, individuation, identity tracking, artifact function, categorization

## Introduction

Imagine the following event sequence: an experimenter reaches into a large box, lifts a square yellow cracker above the center of the box, returns the cracker to the box, and then repeats these actions with a round red candy. If the experimenter then upended the box, adults would expect two objects to fall out, a square yellow cracker and a round red candy. This expectation would depend on at least three abilities: (a) *individuation*, the ability to determine that two objects were in the box; (b) *identity tracking*, the ability to track these objects across events and hence predict that two objects would fall out of the box; and (c) *re-identification*, the ability to specify what features these objects would have. Developmental research has shown that each of these abilities can pose difficulties for infants: under certain conditions, infants fail to correctly individuate objects, they fail to correctly track objects from event to event, and they have limited expectations about what features objects should have when revealed (e.g., Kibbe & Leslie, 2011; Wilcox & Biondi, 2015; Xu & Carey, 1996). The present research explored individuation and identity tracking and examined the origins of these abilities in very young infants.

## Prior Findings

The first task used to study individuation and identity tracking in infancy was devised by Xu and Carey (1996). In this task, infants watch an occlusion event followed by a no-occlusion event. In the occlusion event, infants see an object emerge to one side of a large screen and then return behind it; next, a different object emerges on the opposite side of the screen and again returns behind it (these emergences are often repeated multiple times). In the no-occlusion event, the screen is removed to reveal either both objects (*expected* event) or only one of the objects (*unexpected* event). In another version of the task, devised by Wilcox and Baillargeon (1998), some infants again see an occlusion event in which two different objects emerge alternately from behind a screen (*different-objects* condition), whereas other infants see an occlusion event in which the same object emerges on either side of the screen (*same-object* condition). All infants then see a no-occlusion event in which the screen is lowered to reveal only one object; this event should be unexpected in the different-objects condition, but expected in the same-object condition. Studies with 9- to 12-month-olds using either version of the task (henceforth *standard IIT task*) have yielded similar results, which are summarized below in terms of three main findings.

First, infants succeed at the standard IIT task only if they assign the two occluded objects to distinct categories (e.g., Kingo & Krøjgaard, 2011; Leslie, Xu, Tremoulet, & Scholl, 1998; Rivera & Zawaydeh, 2007; Wilcox & Baillargeon, 1998; Xu & Carey, 1996; Xu, Carey, & Quint, 2004). To illustrate, 12-month-olds succeeded when tested with a ball and a baby bottle (Xu & Carey, 1996), but failed when tested with two different balls (e.g., a small soccer ball with orange, green, and white hexagons and a large red ball covered with glitter; Xu et al., 2004).[1]

Second, the categorical distinctions infants spontaneously encode change over the course of the first year, with critical effects on their performance. Prior to their first birthday, infants who encounter an object typically do not encode its specific object category. However, they do encode more abstract or ontological categorical information about the object, such as whether it is human-like or non-human, animate or inanimate, and so on. Thus, 9- to 10-month-olds

---

1 In simplified IIT tasks, positive results have been obtained even when infants assign the two occluded objects to the same category, as long as the objects differ in featural properties infants have learned to attend to in occlusion events (e.g., Wilcox, 2003; Wilcox & Biondi, 2015; Wilcox & Chapa, 2002; Wilcox & Schweinle, 2002). The present research focused on the more challenging standard IIT task, however, because understanding why categorical information is critical for success in this task is likely to yield important insights into the early development of individuation and identity tracking.

succeeded at standard IIT tasks with two occluded objects from different ontological categories, such as a human-like and a non-human object (e.g., a female red-haired doll and a toy dog; Bonatti, Frot, Zangl, & Mehler, 2002) or an animate and an inanimate object (e.g., a flying bee and a block carried by a hand; Surian & Caldi, 2010), but failed with two occluded objects from the same ontological category that differed only in their specific object categories and/or featural properties (e.g., a ball and a block; Bonatti et al., 2002; Bonatti, Frot, & Mehler, 2005; Krøjgaard, 2000; Surian & Caldi, 2010; Wilcox & Baillargeon, 1998; Xu & Carey, 1996).[2]

Third, although young infants do not spontaneously encode specific object categories, they can be induced to do so via experimental manipulations. To date, two such manipulations have proven effective in standard IIT tasks (Futó, Téglás, Csibra, & Gergely, 2010; Xu, 2002). In one manipulation (Xu, 2002), 9-month-olds heard a distinct label as each object emerged from behind the screen (this manipulation built on prior evidence that young infants typically interpret labels as referring to specific object categories; e.g., Balaban & Waxman, 1997; Waxman & Markow, 1995). In one experiment, the occlusion event involved a toy duck and a ball, and infants heard, "Look, [baby's name], a duck!" or "Look, [baby's name], a ball!" as the corresponding object came into view. Following this manipulation, infants detected a violation when the screen was lowered to reveal only one of the objects. The same positive result was obtained with novel objects and labels ("a fendle", "a toma"), but was eliminated if the two objects were given the same label ("a toy") or were paired with different tones or emotional expressions ("Ah", "Ewy").

In the other manipulation (Futó et al., 2010), 10-month-olds saw a distinct functional

[2] For the purposes of this report, we simply contrast broad ontological categories with more specific object categories, and we leave open the possibility that these more fine-grained categories can be based on perceptual information, conceptual information, or both.

demonstration, accompanied by ostensive-communicative signals, as each object was brought out from behind the screen (according to the natural-pedagogy theory of Csibra and Gergely (2009), ostensive-communicative signals such as hearing one's name or being addressed with infant-directed speech induce infants to interpret a communication as expressing category-relevant information about objects). In one experiment, infants saw a videotaped occlusion event involving two novel objects: One flashed small lights when its handle was pulled, and the other played a melody when its dial was rotated. In each test trial, infants first heard, "Hi, baby, hi!" (in Hungarian), and then they saw an experimenter's hand bring out one of the objects, demonstrate its function several times, and then return it behind the screen. Next, infants heard, "Watch this!" and saw the hand demonstrate the other object's function on the opposite side of the screen. Following this manipulation, infants detected a violation when the screen was lowered to reveal only one of the objects. This positive result was eliminated if either no ostensive-communicative signals were used or no hand was involved in demonstrating the objects' functions (e.g., the dial rotated by itself).

**Research Questions**

The research reviewed above has shed considerable light on the development of individuation and identity tracking in the first year of life. Nevertheless, many questions remain unanswered, and the present research addressed three of them.

***Early categorical advantage?*** We saw in the last section that by 9—10 months, categorical information has a privileged status in standard IIT tasks: Infants succeed as long as they encode the two occluded objects as members of different categories, either spontaneously or as a result of appropriate manipulations. In the present research, we asked whether the privileged role of categorical information could already be observed at a very young age. Specifically, would 4-month-olds succeed at a standard IIT task if induced to assign the two occluded objects to distinct categories?

On the one hand, a positive answer to this question would suggest that the privileged status of categorical information in standard IIT tasks constitutes a fundamental property of the cognitive architecture that supports individuation and identity tracking: From an early age, infants would immediately take advantage of contrastive categorical encodings, when highlighted for them, to individuate and track objects. On the other hand, a negative answer would suggest that some degree of experience at forming and using specific object categories is necessary for infants to successfully recruit these categories in the service of individuation and identity tracking. For example, it could be that during the second half year of life, object categories become more stable and inductively deeper as infants begin to learn labels and other category-relevant information in pedagogical object-centered interactions with caregivers (e.g., Bergelson & Swingley, 2012; Gogate, Maganti, & Laing, 2013; Parise & Csibra, 2012; Vouloumanos, Martin, & Onishi, 2014; Yoon, Johnson, & Csibra, 2008). Infants would then begin to recruit these representations to draw inferences in IIT and other cognitive tasks.

***Early conceptual manipulation?*** As was discussed in the last section, Xu (2002) and Futó et al. (2010) devised manipulations that successfully induced 9- and 10-month-olds tested with a standard IIT task to assign the two occluded objects to distinct object categories. Broadly speaking, manipulations that facilitate categorization in infants can be divided into perceptual and conceptual manipulations. Perceptual manipulations present infants with multiple exemplars from a category (e.g., photographs of different cats), to help infants identify commonalities among the exemplars (e.g., Oakes et al., 2009; Oakes & Ribar, 2005; Quinn, 2002; Quinn, Eimas, & Rosenkrantz, 1993). In contrast, conceptual manipulations provide infants with abstract information about one or more exemplars from a category, such as lexical information, functional information, or information about non-obvious properties (e.g., Baldwin, Markman & Melartin, 1993; Feigenson & Halberda, 2008; Graham, Killbreath & Welder, 2004; Keates & Graham, 2008). In terms of this nomenclature, the manipulations devised by Xu and Futó et al. were both conceptual: In each case, infants saw only one object from each category, and they received information about the object's label or function each time it came into view. Here, we asked whether 4-month-olds could also benefit from a conceptual manipulation in a standard IIT task. Given these very young infants' limited linguistic capabilities, we adopted a function-based manipulation.

In their function-based manipulation, Futó et al. (2010) presented infants with two *causally opaque* artifacts, a "lamp" that flashed lights when its lever was pulled and a "radio" that played music when its dial was rotated. In each case, the link between the artifact's outward physical structure and function could not easily be deduced, and the finding that infants assigned the lamp and the radio to separate categories (and hence succeeded at the task) only when given ostensive-communicative signals was most likely due to this causal opacity. As in the work of Futó et al., much of the research on infants' ability to form function-based categories has used causally opaque artifacts with infants age 10 months and older (e.g., Baumgartner & Oakes, 2011; Booth, Schuler, & Zajicek, 2010; Booth & Waxman, 2002; Hernik & Csibra, 2015; Oakes & Madole, 2008). In this research, pedagogical signals have also been found to bolster infants' encoding of functional information, by conveying that what may seem an arbitrary association (e.g., pulling a lever and lights flashing) actually represents an enduring causal relation that can be exploited in future actions.

To make our function-based manipulation easier for very young infants to comprehend, we used two *causally transparent* artifacts, a masher and tongs (Experiment 1) or a marker and a knife (Experiment 2). Prior investigations that have used causally transparent artifacts suggest that young infants can understand their functions without pedagogical signals (e.g., Booth, 2006; Träuble & Pauen, 2007; Wilcox & Chapa, 2004; Wilcox, Smith, & Woods, 2011; Wilcox, Woods, & Chapa, 2008). To illustrate, Wilcox and Chapa (2004) asked whether 4-month-olds, who typically do not attend to pattern information in occlusion events (Wilcox, 1999), could be primed to do so by learning specific pattern-based categories via arbitrary associations with specific functions (*dotted-pounds*, *striped-pours*). In a hybrid perceptual and conceptual manipulation, infants received three pairs of priming trials; each pair consisted of a *pound* trial in which a dotted container was used to pound a peg and a *pour* trial in which a striped container was used to scoop and pour salt. Different dotted and striped containers were used in each pair of priming trials, and whichever container was not in use in a pair was left on display, to facilitate comparison of the two containers. Next, infants received familiarization trials in which a dotted ball and a striped ball emerged in alternation from behind a tall wide screen, followed by test trials in which the balls emerged in alternation from behind either a tall narrow screen (*narrow-screen* condition) or a short wide screen (*wide-screen* condition). Infants in the narrow-screen condition looked reliably longer than did those in the wide-screen condition, suggesting that they detected a violation when the balls appeared to magically change pattern behind the narrow screen. This effect was eliminated if during the priming trials the container not in use was not displayed, preventing easy comparison of the two containers.

These results make clear that very young infants can understand causally transparent functions such as pounding and pouring. At the same time, however, these results may raise doubts as to whether very young infants could succeed at a standard IIT task when provided with contrastive functional information about the two occluded objects—but *only* these two objects. After all, the 4-month-olds tested by Wilcox and Chapa (2004) required six priming trials involving six different containers, presented two at a time, to succeed at the task. As noted above, however, Wilcox and Chapa used a hybrid perceptual and conceptual manipulation: They asked whether young infants (a) could form *dotted* and *striped* categories via the association, across multiple containers, of each pattern with a different function and (b) could encode two new test objects, a dotted ball and a striped ball, as members of these pattern-based categories. These results left open the possibility that very young infants might succeed at a standard IIT task following a conceptual manipulation in which the two occluded objects themselves were assigned to different function-based categories.

***Early flexible categorical representations?*** In the manipulations of Xu (2002) and Futó et al. (2010), the conceptual information about each occluded object was provided *during* the test trial itself, as the object came into view. Was this timing critical for infants' success? Would infants have succeeded even if this conceptual information had been provided *prior to* the test trial? Or did infants succeed only because they were able to form and recruit these object categories in the same context? At issue is whether early categorical representations are sufficiently flexible and robust that they can be formed in one context and recruited in another, somewhat different context.

The findings of Wilcox and Chapa (2004) discussed above suggest that early categorical representations are indeed flexible: Recall that 4-month-olds first formed *dotted* and *striped* categories in priming trials and then used these categories in test trials to detect surreptitious changes to objects' patterns. Further evidence comes from experiments by Needham and her colleagues that examined whether 4-month-olds could use a newly acquired categorical representation to correctly parse a test display (e.g., Dueker, Modi, & Needham, 2003; Needham & Baillargeon, 2000; Needham, Dueker, & Lockhead, 2005). In a perceptual manipulation, infants first saw a static array of three blocks that differed in pattern and color. Next, infants saw a test display composed of a similar block and a cylinder placed side-by-side. Infants looked reliably longer when the display moved as a single unit, suggesting that they (a) formed a block category when shown the three blocks, (b) recognized the test block as another exemplar from this category, and hence (c) inferred that the test block and the cylinder were distinct objects. Building on these results, we asked whether 4-month-olds who first received functional demonstrations designed to help them assign two objects to different categories would subsequently be able to recruit these categorical encodings to individuate and track the objects.

***Summary***. The present research sought to address three inter-related questions concerning the importance and use of categorical information in early individuation and identity tracking. First, could infants as young as 4 months of age make use of contrastive categorical representations to succeed at a standard IIT task? Second, could infants be induced to establish these representations via causally transparent functional demonstrations? Finally, could infants recruit these representations even if established prior to test?

## Experiment 1

Experiment 1 examined whether 4-month-olds would succeed at a standard IIT task involving two tools, a masher and a pair of tongs, following simple functional demonstrations in which the masher was used to compress sponges and the tongs were used to lift them. Given previous evidence that young infants understand simple mechanical events with compressible objects (e.g., Aguiar & Baillargeon, 1998; Baillargeon, 1987; Hauf, Paulus, & Baillargeon, 2012), it seemed plausible that 4-month-olds would easily grasp the link between each tool's structure and function.

Infants were assigned to a function or no-function group; within each group, infants were further assigned to a different-objects or same-object condition (as in Wilcox and Baillargeon 1998). All infants received two demonstration trials, one familiarization trial, and one test trial.

***Function group different-objects condition***. The demonstration trials in the different-objects condition of the function group consisted of a masher trial and a tongs trial (Fig. 1). In the *masher* trial, a row of three sponges rested on a tray centered on the floor of a puppet-stage apparatus; an experimenter's hand (which reached into the apparatus through a window in the back wall) held a masher and compressed each sponge in turn, from left to right (from infants' perspective). Each cycle of compressing the sponges lasted about 30 s, and cycles were repeated until the trial ended (see Procedure). The *tongs* trial was identical except that the hand held tongs and lifted each sponge in turn. The order of the two demonstration trials was counterbalanced across infants.

The familiarization and test trial each had an initial phase and a final phase; looking times during the two phases were computed separately. During the initial phase of a trial, the hand performed the scripted actions appropriate for the trial, ending with a final scene; during the final phase, infants watched this scene until the trial ended. The duration of the initial phase was fixed, but that of the final phase was infant-controlled.

The initial phase of the familiarization trial lasted 40 seconds (Fig. 2). To start, the hand brought out one of the objects (e.g., the masher) to the right of a large screen, gently tilted the object left and right for 6 s, and returned it behind the screen. After a 2-s pause, the hand brought out the other object (e.g., the tongs) to the left of the screen, tilted the object for 6 s, and returned it behind the screen. This entire sequence was then repeated a second time. To help maintain infants' attention, a bell was rung before each object was brought out. During the final phase of the familiarization trial, no further object emergences occurred; infants saw the upright screen until the trial ended.

The initial phase of the test trial lasted 42 seconds (Fig. 2). After each tool was brought out twice in alternation (40 s), as in the familiarization trial, the screen was lowered to the apparatus floor (2 s). During the final phase of the test trial, the hand tilted the last object that had been brought out (e.g., the tongs) until the trial ended (the other object was surreptitiously removed before the screen was lowered). In both the familiarization and test trials, the object that was brought out last was always the one from the second demonstration trial.

***Function group same-object condition***. The demonstration trials in the same-object condition of the function group were identical to those in the different-objects condition, and the order of the masher and tongs trials was again counterbalanced across infants. In the initial phases of the familiarization and test trials, however, the same object (e.g., the masher) was brought out on either side of the screen (Fig. 2; for a closer alignment of the experimenter's actions across conditions, two identical objects were used in these trials). The object shown in the familiarization and test trials was always the object from the second demonstration trial.

***No-function group different-objects and same-object conditions.*** Trials in the no-function group different-objects and same-object conditions were identical to those in the function group different-objects and same-objects conditions, respectively, with one exception: In the demonstration trials, the hand performed the same compressing (masher trial) and lifting (tongs trial) actions a few centimeters above the sponges, so that the masher and tongs did not come in contact with them (Fig. 1). Prior research indicated that young infants do not assign objects that are used in contrastive non-functional actions to distinct categories (e.g., Booth, 2006; Booth & Waxman, 2002; Wilcox & Chapa, 2004; Wilcox et al., 2008).

***Predictions***. With respect to the function group, we predicted that if infants (a) understood the different functional actions (compressing vs. lifting) performed in the demonstration trials, (b) were induced by these demonstrations to establish separate categorical representations for the masher and tongs (e.g., *compresser* vs. *lifter*), and (c) were able to recruit these representations in the test trial to individuate and track the objects, then infants in the different-objects condition should expect to see both objects when the screen was lowered, whereas infants in the same-object condition should expect to see only one object (although two identical objects were used, infants were likely to assume that a single object was involved because they had no information to suggest otherwise). We thus predicted that infants in the different-objects condition would look reliably longer during the final phase of the test trial than infants in the same-object condition.

As for the no-function group, we predicted that infants would fail to encode the masher and tongs as members of distinct categories and hence would look equally in the different-objects and same-object conditions during the final phase of the test trial. Such a negative result would help rule out alternative interpretations of a positive result in the function group (e.g., prior exposure to the masher and tongs and/or their different motions was sufficient to induce infants to individuate and track the two objects in the test trial).

***Method***

*Participants*

Participants were 48 healthy term 4-month-olds (23 male, *M* = 4;24, range = 4;0—5;22). Another 17 infants (6 from the function group, 11 from the no-function group) were tested but excluded: 7 were overly fussy, 5 looked the maximum amount of time allowed across trials, 2 were distracted (e.g., by their clothes), 2 were inattentive during the initial phase of the test trial, and 1 (in the same-object condition of the no-function group) had a test looking time over 3 standard deviations from the condition mean. Twelve infants were randomly assigned to the four treatments formed by crossing the two groups (function or no-function) and the two conditions (different-objects or same-object).

*Apparatus and stimuli*

The apparatus consisted of a brightly lit display booth (106 cm high × 101 cm wide × 57 cm deep) mounted 76 cm above the floor of the test room. The infant faced a large opening (41 × 95) in the front of the apparatus; between trials, a curtain was lowered by a supervisor to hide this opening. Inside the apparatus, the side walls were painted white, and the back wall and floor were covered with pastel adhesive paper.

The experimenter wore a white shirt and stood behind a short window (14 × 53) centered in the back wall of the apparatus, 19 cm above the floor; the top third of the window was filled with muslin. A muslin fringe extended across the back wall below the window, to conceal the trap door that was used by a hidden assistant to surreptitiously remove objects in the test trial.

The tools were two identical green mashers (each 16.5 × 9.5 × 8) and two identical red and silver tongs (each 19.5 × 14 × 5). In the demonstration trials, a wooden tray (1.5 × 46 × 13) held three beige sponges that varied somewhat in shape (turtle-shell shaped, round, and bone shaped) and size (at the largest points, 5 × 8 × 11). In the familiarization and test trials, a cream-colored screen (35 × 39) stood centered on the apparatus floor, 20 cm from the back wall. The screen was mounted on a thin rod that stretched between the two side walls; at the end of the test trial, another hidden assistant rotated the right end of the rod, out of view, to lower the screen. When upright, the screen hid the middle portion of the window in the back wall and thus concealed the experimenter's actions behind the screen, to avoid providing visual cues as to how many tools were present. To also avoid providing auditory cues, the experimenter released the tools on a strip of felt when returning them behind the screen. Before the screen was lowered in the test trial, this strip of felt was removed together with the penultimate object brought out by the experimenter.

During each session, one camera captured an image of the events, and another camera captured an image of the infant. The two images were combined, projected onto a computer monitor located behind the apparatus, and watched by the supervisor to confirm that the events followed the prescribed scripts. Recorded sessions were also checked off-line for accuracy.

*Procedure*

Infants sat on a parent's lap, centered in front of the apparatus; parents were instructed to remain silent and close their eyes during the test trial. During the familiarization and test trials, two naïve observers hidden on either side of the apparatus monitored the infant's looking behavior, and looking times were computed using the primary observer's responses; from their viewpoints, the observers could not determine to what condition the infant was assigned. To ensure that the primary observer was also naïve about the infant's group, this observer was absent from the test room during the demonstration trials. Interobserver agreement during the test trial was measured as the proportion of 100-ms intervals in which the observers agreed on whether or not the infant was looking at the event. Agreement for all infants in this report averaged 96%.

Each demonstration trial ended when infants (a) looked away for 2 consecutive seconds after having looked for at least 30 cumulative seconds or (b) looked for 60 cumulative seconds. The 30-s minimum value of each trial ensured that infants had the opportunity to see one cycle of the three sponges being compressed (masher trial) or lifted (tongs trial).

Infants were highly attentive during the initial phase of the familiarization trial, when the objects were brought out from behind the screen; across groups and conditions, infants looked, on average, for 33.5/40 s (Table 1). The final phase of the trial ended when infants (a) looked away for 2 consecutive seconds after having looked for at least 5 cumulative seconds or (b) looked for 30 cumulative seconds. The final phase was kept relatively short as infants simply saw the upright screen.

Infants were also attentive during the initial phase of the test trial, when the objects were brought out and the screen was finally lowered; infants looked, on average, for 34.5/42 s. The final phase of the test trial ended when infants (a) looked away for 0.5 consecutive seconds after having looked for at least 6 cumulative seconds or (b) looked for 60 cumulative seconds. The 6-s minimal value was chosen to give infants time, after the screen was lowered, to process the display and determine whether it was consistent with their expectations. Finally, because the hand continuously tilted the object left and right during the final phase of the trial, infants' attention was easily recaptured; as a result, a look-away value of 0.5 consecutive seconds made it possible to detect when infants had sufficiently processed the display to determine whether it was expected (for similar criteria, see e.g., Wilcox & Baillargeon, 1998).

***Results***

To correct for possible positive skew, all looking times in this report were log-transformed, and analyses were conducted on the log-transformed data (e.g., Csibra et al. 2016); nevertheless, for ease of communication, raw looking times are provided in this report. Preliminary analyses of the test data revealed no interaction of group and condition with sex or object order; the data were therefore collapsed across the latter two factors.

Looking times during the two demonstration trials were averaged and analyzed by an analysis of variance (ANOVA) with group (function or no-function) and condition (different-objects or same-object) as between-subjects factors. The analysis yielded a significant main effect of group, $F(1, 44) = 5.24$, $p = 0.027$, indicating that infants in the function group ($M$ = 50.4, $SD$ = 7.2) looked longer overall than those in the no-function group ($M$ = 45.5, $SD$ = 7.1). However, neither the main effect of condition nor the Group × Condition interaction was significant, both $F$s(1, 44) < 1, indicating that within each group, looking times were similar across conditions.

Looking times during the final phase of the familiarization trial were analyzed as above. No effects were significant, all $F$s(1, 44) ≤ 1.37, $p \geq 0.249$. Infants in the two groups and conditions thus looked about equally at the upright screen during the final phase of the trial.

Looking times during the final phase of the test trial (Fig. 3) were also analyzed as above. The main effects of group and condition were not significant, both $F$s(1, 44) ≤ 1.63, $p \geq 0.208$, but the Group × Condition interaction was significant, $F(1, 44) = 9.59$, $p = 0.003$, $\eta_p^2 = 0.179$. Planned comparisons revealed that in the function group, infants in the different-objects condition ($M$ = 20.1, $SD$ = 9.0) looked reliably longer than those in the same-object condition ($M$ = 12.6, $SD$ = 8.6), $F(1, 44) = 9.56$, $p = 0.003$, Cohen's $d$ = 1.17. In the no-function group, in contrast, infants in the different-objects ($M$ = 13.1, $SD$ = 4.9) and same-object ($M$ = 16.9, $SD$ = 7.1) conditions looked about equally, $F(1, 44) = 1.66$, $p = 0.205$, $d$ = -0.58.

***Further Results***

To confirm our key finding that infants in the different-objects condition of the function group detected a violation when the screen was lowered to reveal only one of the tools, we tested 12 additional infants in this condition (7 male, $M$ = 4;13, range = 4;1—4;26); one other infant was excluded for being inattentive in the demonstration trials. We then re-analyzed the test data of Experiment 1 substituting this new set of infants for its counterpart (function group different-objects condition). Once again, the main effects of group and condition were not significant, both *Fs*(1, 44) < 1, but the Group × Condition interaction was significant, $F(1, 44) = 6.67$, $p = 0.013$, $\eta_p^2 = 0.132$. A planned comparison revealed that infants in this new set ($M = 19.8$, $SD = 11.0$) looked reliably longer than those in the same-object condition of the function group, $F(1, 44) = 6.08$, $p = 0.018$, $d = 0.88$, thus replicating our key finding (Fig. 3).

### *Discussion*

In the function group, infants in the different-objects condition and its replication looked reliably longer when the screen was lowered to reveal one object than did infants in the same-object condition. These results suggest that infants understood the different functional actions performed in the demonstration trials and were induced by these actions to assign the masher and tongs to distinct categories (e.g., *compresser* vs. *lifter*). These categorical encodings persisted in the test trial and enabled infants to successfully individuate and track the masher and tongs.

In the no-function group, in contrast, infants in the different-objects and same-object conditions looked about equally when the screen was lowered to reveal one object. Because the actions shown in the demonstration trials were non-functional, infants did not assign the masher and tongs to distinct categories. As a result, infants failed at the task, in line with prior negative findings with young infants in standard IIT tasks.

## Experiment 2

Experiment 2 sought to replicate the findings of Experiment 1 using two new causally transparent tools, a marker and a knife; the marker was used to draw lines on dry-erase boards, and the knife was used to cut balls of play dough. Although we knew of no evidence collected with young infants involving drawing events, there was prior evidence that infants in the first year of life understand simple cutting events (Needham & Baillargeon, 1997; Tzelnic, Kuhlmeier, & Hauser, 2016).

The design of Experiment 2 was identical to that of Experiment 1 except that the tools were the marker and knife. In the *marker* demonstration trial of the function group (Fig. 4), three dry-erase boards lay in a row on a tray, and the experimenter's hand used a marker, held vertically, to draw four lines on each board. In the *knife* demonstration trial, three play-dough balls lay in a row on the tray, and the hand used a knife, held horizontally, to slice each ball in thirds, from front to back. As in Experiment 1, each cycle of drawing or cutting over the three target objects (moving from left to right) lasted about 30 s, and cycles were repeated until the trial ended. In the demonstration trials of the no-function group, the hand performed identical drawing and cutting actions a few centimeters above the dry-erase boards and play-dough balls, respectively. The familiarization and test trials were the same as in Experiment 1 except that they involved the marker and knife, held vertically (Fig. 5).

### *Method*

#### *Participants*

Participants were 48 healthy term 4-month-olds (24 male, *M* = 4;19, range = 3;26-5;18). Another 15 infants (6 from the function group, 9 from the no-function group) were excluded: 6 were overly fussy, 3 were distracted, 1 looked the maximum amount of time allowed across trials, 3 were inattentive during the initial phase of the test trial, and 2 (1 in the same-object condition of the function group and 1 in the different-objects condition of the no-function group) had a test looking time over 3 standard deviations from the condition mean.

#### *Apparatus and Stimuli*

The apparatus and stimuli were identical to those in Experiment 1 except as follows. The tools were two identical red markers (each 20 cm × 4 cm in diameter and formed by enclosing a regular red marker inside a red cardboard tube) and two identical green plastic knives (each 26 × 6 × 1) decorated with dots. In the demonstration trials, a wooden tray (0.5 × 46 × 21) held three white dry-erase boards (each 0.5 × 10 × 10) or three irregular balls of beige play dough (each about 10 cm in diameter).

*Procedure*

The procedure was identical to that of Experiment 1. Infants were attentive during the initial phase of the familiarization trial (34.2/40 s) and test trial (34.6/42 s).

***Results***

Looking times were analyzed as in Experiment 1. No effects were significant for the demonstration trials, all *F*s(1, 44) ≤ 1.98, $p \geq 0.167$, or the final phase of the familiarization trial, all *F*s(1, 44) ≤ 1.50, $p \geq 0.227$. Infants in the two groups and conditions thus looked about during these trials (Table 1).

Looking times during the final phase of the test trial (Fig. 3) were analyzed as above. Neither the main effect of group, $F(1, 44) = 2.20$, $p = 0.145$, nor the main effect of condition, $F(1, 44) = 3.62$, $p = 0.064$, were significant. The Group × Condition interaction was significant, $F(1, 44) = 5.83$, $p = 0.020$, $\eta_p^2 = 0.117$. Planned comparisons revealed that in the function group, infants in the different-objects condition ($M = 25.0$, $SD$ =14.9) looked reliably longer than those in the same-object condition ($M = 12.1$, $SD = 5.9$), $F(1, 44) = 9.32$, $p = 0.004$, $d = 1.12$. In the no-function group, in contrast, infants in the different-objects ($M = 12.9$, $SD = 6.1$) and same-object ($M = 13.8$, $SD = 6.1$) conditions looked about equally, $F(1, 44) < 1$, $d = -0.16$.

***Further Results***

As in Experiment 1, we tested 12 additional infants in the different-objects condition of the function group (6 male, *M* = 4;10, range = 4;1—4;25); three other infants were excluded because they were fussy, inattentive, or distracted. We re-analyzed the test data of Experiment 2 substituting this new set of infants for its counterpart. Once again, the main effects of group, $F(1, 44) = 1.67$, $p = 0.203$, and condition, $F(1, 44) = 2.86$, $p = 0.098$, were not significant, but the Group × Condition interaction was significant, $F(1, 44) = 4.75$, $p = 0.035$, $\eta_p^2 = 0.097$. A planned comparison revealed that infants in this new set ($M = 25.5$, $SD = 18.7$) looked reliably longer than those in the same-object condition of the function group, $F(1, 44) = 7.49$, $p = 0.009$, $d = 0.98$, thus replicating our key finding (Fig. 3).

### *Discussion*

In the function group, infants in the different-objects condition and its replication looked reliably longer when the screen was lowered to reveal one object than did infants in the same-object condition; in the no-function group, infants in the two conditions looked about equally. These results extend those of Experiment 1 to two new causally transparent tools, a marker and a knife. Infants in the function group understood the different functional actions performed in the demonstration trials and were led by these actions to assign the marker and knife to distinct categories (e.g., *drawer* vs. *cutter*). These categorical encodings persisted in the test trial, enabling infants to successfully individuate and track the two tools.

## General Discussion

In two experiments, 4-month-olds first watched functional demonstrations for two different tools, a masher and tongs (Experiment 1) or a marker and a knife (Experiment 2). Next, infants saw both tools in alternation (different-objects condition), or the same tool (same-object condition), brought out on either side of a screen, which was then lowered to reveal one tool. In both experiments, infants in the different-objects condition looked reliably longer than those in the same-object condition, and this effect was eliminated if the demonstrations involved similar but non-functional actions. These results bear directly on the three questions raised in the Introduction.

***Early categorical advantage.*** In the Introduction, we reviewed extensive evidence that infants succeed at a standard IIT task as long as they can assign the two occluded objects to distinct categories, either spontaneously or via experimental manipulations. Our results indicate that the privileged status of categorical information can be observed from a very young age: Even at 4 months, infants succeed at a standard IIT task when induced to assign the two occluded objects to distinct categories. These results naturally raise the following question: Why is categorical information, from a very early age, critical for success at standard IIT tasks? At least two hypotheses have been proposed to date.

According to the *individuation* hypothesis, assigning the two occluded objects to distinct *kinds* (i.e., inductively deep categories) supports the individuation process in standard IIT tasks (e.g., Xu & Carey, 1996). Because infants understand that objects cannot change kinds, then upon noticing that the second object to emerge from behind the screen belongs to a different kind than the first object, infants infer that two objects are present and expect both to be revealed when the screen is removed. From this perspective, our results indicate that contrastive functional demonstrations can lead very young infants to assign objects to distinct kinds, making possible correct individuation.

According to the *identity-tracking* hypothesis, categorical information supports the identity-tracking process in standard IIT tasks (e.g., Stavans, Li, & Baillargeon, 2016). As the two occluded objects emerge alternately from behind the screen, the object-tracking system attends only to the spatiotemporal information available and wrongly assumes that a single object is present (e.g., Pylyshyn, 2007). In contrast, the physical-reasoning system recognizes that two distinct objects are present and attempts to update the object-tracking system accordingly. Whether this update succeeds or fails depends on working-memory constraints. When communicating with the object-tracking system about the two objects, the physical-reasoning system must use a unique descriptor for each object. Categorical descriptors—whether they refer to inductively deep kinds or shallow perceptual categories—are particularly advantageous because they do not tax working memory, resulting in a successful update of the object-tracking system and hence leading infants to expect two objects when the screen is removed. From this perspective, our results indicate that from a very early age, contrastive functional demonstrations make available unique categorical descriptors for the update of the object-tracking system, resulting in correct identity tracking.

The two preceding hypotheses assume that infants in the present experiments succeeded because the demonstration trials induced them to establish distinct categorical representations for the two tools. Is this assumption correct? It might be suggested that perhaps the demonstration trials simply highlighted the *featural differences* between the tools. Although possible, this alternative hypothesis is unlikely, for several reasons. First, Xu and her colleagues found that infants who failed at standard IIT tasks nevertheless gave evidence that they noticed the featural differences between the two occluded objects: Infants who saw the same object emerge on either side of the screen looked reliably less across successive emergences than did infants who saw two different objects (e.g., Xu & Carey, 1996; Xu et al., 2004). Second, evidence from physical-reasoning tasks indicates that by 4 months of age, most infants attend to the sizes and shapes of occluded objects (e.g., Wang, Baillargeon, & Brueckner, 2004; Wilcox, 1999). Third, neuroimaging evidence using functional near-infrared spectroscopy also indicates that infants age 5 months and older use shape information to determine whether one or two objects are present behind a screen (e.g., Wilcox, Hawkins, Hirshkowitz, & Boas, 2014; Wilcox, Stubbs, Hirshkowitz, & Boas, 2012). Finally, evidence from simplified IIT tasks indicates that young infants can use featural differences to individuate and track objects under reduced working-memory load (e.g., Wilcox & Baillargeon, 1998; Wilcox & Schweinle, 2002).

Together, these results suggest that the positive findings of the present experiments arose not because the demonstration trials enhanced infants' attention to the featural properties of the two occluded objects, but because these trials led infants to assign the two objects to distinct categories. Future research can explore whether these categorical representations supported the individuation process, the identity-tracking process, or some combination of the two.

***Early conceptual manipulation.*** Xu (2002) and Futó et al. (2010) used conceptual manipulations—a label-based and a function-based manipulation, respectively—to induce 9- and 10-month-olds to succeed at a standard IIT task; both manipulations also included ostensive-communicative signals. The present research extends these results by showing that conceptual manipulations involving simple, causally transparent functional demonstrations can induce categorical encoding in infants as young as 4 months of age, without ostensive-communicative signals (recall that the experimenter remained silent and only her hands were visible). In each demonstration trial, the link between the structure and function of each tool was easy to grasp, and infants understood it without pedagogical assistance.

Future research can examine whether perceptual manipulations might also be effective in leading very young infants to succeed at standard IIT tasks. Recall that Needham et al. (2005) found that 4-month-olds correctly parsed a test display composed of an adjacent block and cylinder after seeing a static array of three similar blocks. In the same vein, one could ask whether 4-month-olds might succeed at a standard IIT task following exposure to two arrays of similar objects (e.g., three blocks and three cylinders). Positive results would extend the present findings to a different type of experimental manipulation and also bear on the debate between the individuation and identity-tracking hypotheses: It would be difficult to argue that inductively deep kinds are necessary for individuation in standard IIT tasks if shallow perceptual categories formed by brief exposure to arrays of objects were sufficient for success at these tasks.

***Early flexible categorical representations.*** In the manipulations of Xu (2002) and Futó et al. (2010), the conceptual information about each occluded object was provided during the test trial itself. The present results indicate that this timing is not essential for infants' success. In each experiment, infants saw the functional demonstrations for the two tools in trials administered at the start of the session. Nevertheless, infants were able to recruit the categorical representations formed in these trials to correctly individuate and track the tools in the test trial.

Future research can extend these results by examining how long a delay infants can withstand between the demonstration and test trials. Needham and her colleagues found that exposure to the static array of three blocks helped 5-month-olds parse the test display even if this exposure occurred three days prior to test (e.g., Dueker et al., 2003; Needham et al., 2005). It would be interesting to explore whether conceptual or perceptual manipulations performed a few days prior to test could still lead very young infants to succeed at standard IIT tasks.

### *Conclusion*

The present results indicate that causally transparent functional demonstrations can induce success in a standard IIT task in infants as young as 4 months of age, even if performed before the task and without pedagogical signals. These results shed light on early individuation and identity tracking and raise interesting questions for future research about the cognitive architecture that supports these abilities. These results also provide further evidence that from a very young age, categorical representations established for objects in one context are immediately put to use when reasoning about the objects in a different context.

**References**

Aguiar, A., & Baillargeon, R. (1998). Eight-and-a-half-month-old infants' reasoning about containment events. *Child Development, 69*(3), 636-653. doi: 10.2307/1132195

Baillargeon, R. (1987). Young infants' reasoning about the physical and spatial characteristics of a hidden object. *Cognitive Development, 2,* 179-200. doi: 10.1016/S0885-2014(87)90043-8

Balaban, M. T., & Waxman, S. R. (1997). Do words facilitate object categorization in 9-month-old infants? *Journal of Experimental Child Psychology, 64*(1), 3-26. doi: 10.1006/jecp.1996.2332

Baldwin, D.A., Markman, E.M., & Melartin, R.L. (1993). Infants' ability to draw inferences about nonobvious object properties: Evidence from exploratory play. *Child Development, 64*(3), 711-728. doi 10.1111/j.1467-8624.1993.tb02938.x

Baumgartner, H. A., & Oakes, L. M. (2011). Infants' developing sensitivity to object function: attention to features and feature correlations. *Journal of Cognition and Development, 12*(3), 275-298. doi: 10.1080/15248372.2010.542217

Bergelson, E., & Swingley, D. (2012). At 6-9 months, human infants know the meanings of many common nouns. *Proceedings of the National Academy of Sciences of the United States of America, 109*(9), 3253-3258. doi: 10.1073/pnas.1113380109

Bonatti, L. L., Frot, E., & Mehler, J. (2005). What face inversion does to infants' counting abilities. *Psychological Science, 16*(7), 506-510. doi: 10.1111/j.0956-7976.2005.01565.x

Bonatti, L., Frot, E., Zangl, R., & Mehler, J. (2002). The human first hypothesis: Identification of conspecifics and individuation of objects in the young infant. *Cognitive Psychology, 44*(4), 388-426. doi: 10.1006/cogp.2002.0779

Booth, A. E. (2006). Object function and categorization in infancy: two mechanisms of facilitation. *Infancy, 10*(2), 145-169. doi: 10.1207/s15327078in1002_3

Booth, A. E., Schuler, K., & Zajicek, R. (2010). Specifying the role of function in infant categorization. *Infant Behavior & Development, 33*(4), 672-684. doi: 10.1016/j.infbeh.2010.09.003

Booth, A. E., & Waxman, S. (2002). Object names and object functions serve as cues to categories for infants. *Developmental Psychology, 38*(6), 948-957. doi: 10.1037/0012-1649.38.6.948

Csibra, G., & Gergely, G. (2009). Natural pedagogy. *Trends in Cognitive Sciences, 13*(4), 148-153. doi: 10.1016/j.tics.2009.01.005

Csibra, G., Hernik, M., Mascaro, O., Tatone, D., & Lengyel, M. (2016). Statistical treatment of looking-time data. *Developmental Psychology, 52*(4), 521-536. doi: 10.1037/dev0000083

Dueker, G. L., Modi, A., & Needham, A. (2003). 4.5-month-old infants' learning, retention and use of object boundary information. *Infant Behavior & Development, 26*(4), 588-605. doi: 10.1016/j.infbeh.2003.05.002

Feigenson, L., & Halberda, J. (2008). Conceptual knowledge increases infants' memory capacity. *Proceedings of the National Academy of Sciences of the United States of America, 105*(29), 9926-9930. doi: 10.1073/pnas.0709884105

Futó, J., Téglás, E., Csibra, G., & Gergely, G. (2010). Communicative function demonstration induces kind-based artifact representation in preverbal infants. *Cognition, 117*(1), 1-8. doi: 10.1016/j.cognition.2010.06.003

Gogate, L. J., Maganti, M., & Laing, K. B. (2013). Maternal naming of object wholes versus parts to preverbal infants: A fine-grained analysis of scaffolding at 6–8 months. *Infant Behavior and Development, 36*(3), 470-479. doi: 10.1016/j.infbeh.2013.03.012

Graham, S. A., Kilbreath, C. S. & Welder, A. N. (2004). Thirteen-month-olds rely on shared labels and shape similarity for inductive inferences. *Child Development, 75*(2)*,* 409–427. doi: 10.1111/j.1467-8624.2004.00683.x

Hauf, P., Paulus, M., & Baillargeon, R. (2012). Infants use compression information to infer objects' weights: Examining cognition, exploration, and prospective action in a preferential-reaching task. *Child Development, 83*(6), 1978-1995. doi: 10.1111/j.1467-8624.2012.01824.x

Hernik, M., & Csibra, G. (2015). Infants learn enduring functions of novel tools from action demonstrations. *Journal of Experimental Child Psychology, 130*, 176-192. doi: 10.1016/j.jecp.2014.10.004

Keates, J., & Graham, S. A. (2008). Category markers or attributes: Why do labels guide infants' inductive inferences? *Psychological Science, 19*(12), 1287-1293. doi: 10.1111/j.1467-9280.2008.02237.x

Kibbe, M. M., & Leslie, A. M. (2011). What do infants remember when they forget? Location and identity in 6-month-olds' memory for objects. *Psychological Science, 22*(12), 1500-1505. doi: 10.1177/0956797611420165

Kingo, O. S., & Krøjgaard, P. (2011). Object manipulation facilitates kind-based object individuation of shape-similar objects. *Cognitive Development, 26*(2), 87-103. doi: 10.1016/j.cogdev.2010.08.009

Krøjgaard, P. (2000). Object individuation in 10-month-old infants: Do significant objects make a difference? *Cognitive Development, 15*, 169-184. doi: 10.1016/S0885-2014(00)00020-4

Leslie, A. M., Xu, F., Tremoulet, P. D., & Scholl, B. J. (1998). Indexing and the object concept: Developing 'what' and 'where' systems. *Trends in Cognitive Sciences, 2*(1), 10-18. doi: 10.1016/S1364-6613(97)01113-3

Needham, A., & Baillargeon, R. (1997). Object segregation in 8-month-old infants. *Cognition, 62*(2), 121-149. doi: 10.1016/S0010-0277(96)00727-5

Needham, A., & Baillargeon, R. (2000). Infants' use of featural and experiential information in segregating and individuating objects: A reply to Xu, Carey, and Welch (1999). *Cognition, 74*(3)*,* 255-284.

Needham, A., Dueker, G., & Lockhead, G. (2005). Infants' formation and use of categories to segregate objects. *Cognition, 94*(3), 215-240. doi: 10.1016/j.cognition.2004.02.002

Oakes, L. M., Horst, J. S., Kovack-Lesh, K. A., & Perone, S. (2009). How infants learn categories. In A. Woodward & A. Needham (Eds.), *Learning and the infant mind* (pp. 144-171). New York, NY: Oxford University Press.

Oakes, L. M., & Madole, K. L. (2008). Function revisited: How infants construe functional features in their representation of objects. *Advances in Child Development and Behavior, 36*, 135–185. doi: 10.1016/S0065-2407(08)00004-9

Oakes, L. M., & Ribar, R. J. (2005). A comparison of infants' categorization in paired and successive presentation familiarization tasks. *Infancy, 7*(1), 85-98. doi: 10.1207/s15327078in0701_7

Parise, E., & Csibra, G. (2012). Electrophysiological evidence for the understanding of maternal speech by 9-month-old infants. *Psychological Science, 23*(7), 728-733. doi: 10.1177/0956797612438734

Pylyshyn, Z. W. (2007). *Things and places: How the mind connects with the world*. Cambridge, MA: MIT Press.

Quinn, P. C. (2002). Category representation in young infants. *Current Directions in Psychological Science, 11*(2), 66-70. doi: 10.1111/1467-8721.00170

Quinn, P. C., Eimas, P. D., & Rosenkrantz, S. L. (1993). Evidence for representations of perceptually similar natural categories by 3-month-old and 4-month-old infants. *Perception, 22*(4), 463-475. doi: 10.1068/p220463

Rivera, S. M., & Zawaydeh, A. N. (2007). Word comprehension facilitates object individuation in 10- and 11-month-old infants. *Brain Research, 1146*, 146-157. doi: 10.1016/j.brainres.2006.08.112

Stavans, M., Li, X., & Baillargeon, R. (2016). Individuation and identity tracking in infancy: A new account. Manuscript under review.

Surian, L., & Caldi, S. (2010). Infants' individuation of agents and inert objects. *Developmental Science, 13*(1), 143-150. doi: 10.1111/j.1467-7687.2009.00873.x

Träuble, B., & Pauen, S. (2007). The role of functional information for infant categorization. *Cognition, 105*(2), 362-379. doi: 10.1016/j.cognition.2006.10.003

Tzelnic, T., Kuhlmeier, V. A., & Hauser, M. (2016). Nine-month-old infants understand sharpness as a causal property. Manuscript under review.

Vouloumanos, A., Martin, A., & Onishi, K. H. (2014). Do 6-month-olds understand that speech can communicate? *Developmental Science, 17*(6), 872-879. doi: 10.1111/desc.12170

Wang, S., Baillargeon, R., & Brueckner, L. (2004). Young infants' reasoning about hidden objects: evidence from violation-of-expectation tasks with test trials only. *Cognition, 93*(3), 167-198. doi: 10.1016/j.cognition.2003.09.012

Waxman, S. R., & Markow, D. B. (1995). Words as invitations to form categories: Evidence from 12- to 13-month-old infants. *Cognitive Psychology, 29*(3), 257-302. doi: 10.1006/cogp.1995.1016

Wilcox, T. (1999). Object individuation: infants' use of shape, size, pattern, and color. *Cognition, 72*(2), 125-166. doi: 10.1016/S0010-0277(99)00035-9

Wilcox, T. (2003). Event-mapping tasks: Investigating the effects of prior information and event complexity on performance. *Infant Behavior and Development, 26*, 568-587. doi: 10.1016/j.infbeh.2003.05.001

Wilcox, T., & Baillargeon, R. (1998). Object individuation in infancy: The use of featural information in reasoning about occlusion events. *Cognitive Psychology, 37*, 97-155. doi: 10.1006/cogp.1998.0690

Wilcox, T., & Biondi, M. (2015). Object processing in the infant: lessons from neuroscience. *Trends in Cognitive Sciences, 19*(7), 406-413. doi: 10.1016/j.tics.2015.04.009

Wilcox, T., & Chapa, C. (2002). Infants' reasoning about opaque and transparent occluders in an individuation task. *Cognition, 85*(1), B1-B10. doi: 10.1016/S0010-0277(02)00055-0

Wilcox, T., & Chapa, C. (2004). Priming infants to attend to color and pattern information in an individuation task. *Cognition, 90*(3), 265-302. doi: 10.1016/S0010-0277(03)00147-1

Wilcox, T., Hawkins, L., Hirshkowitz, A., & Boas, D. A. (2014). Cortical activation to object shape and speed of motion during the first year. *NeuroImage, 99*, 129-141. doi: 10.1016/j.neuroimage.2013.08.045

Wilcox, T., & Schweinle, A. (2002). Object individuation and event mapping: Developmental changes in infants' use of featural information. *Developmental Science, 5*(1), 132-150. doi: 10.1111/1467-7687.00217

Wilcox, T., Smith, T. & Woods, R. (2011). Priming infants to use pattern information in an object individuation task: The role of comparison. *Developmental Psychology, 47*(3), 886-897. doi: 10.1037/a0021792

Wilcox, T., Stubbs, J., Hirshkowitz, A., & Boas, D. A. (2012). Functional activation of the infant cortex during object processing. *NeuroImage, 62*(3), 1833-1840. doi: 10.1016/j.neuroimage.2012.05.039

Wilcox, T., Woods, R., & Chapa, C. (2008). Color–function categories that prime infants to use color information in an object individuation task. *Cognitive Psychology, 57*(3), 220-261. doi: 10.1016/j.cogpsych.2008.02.001

Xu, F. (2002). The role of language in acquiring object kind concepts in infancy. *Cognition, 85*, 223-250. doi: 10.1016/S0010-0277(02)00109-9

Xu, F., & Carey, S. (1996). Infants' metaphysics: The case of numerical identity. *Cognitive Psychology, 30*(2), 111-153. doi: 10.1006/cogp.1996.0005

Xu, F., Carey, S., & Quint, N. (2004). The emergence of kind-based object individuation in infancy. *Cognitive Psychology, 49*(2), 155-190. doi: 10.1016/j.cogpsych.2004.01.001

Yoon, J. M. D., Johnson, M. H., & Csibra, G. (2008). Communication-induced memory biases in preverbal infants. *Proceedings of the National Academy of Sciences of the United States of America, 105*(36), 13690-13695. doi: 10.1073/pnas.0804388105

**Figure Captions**

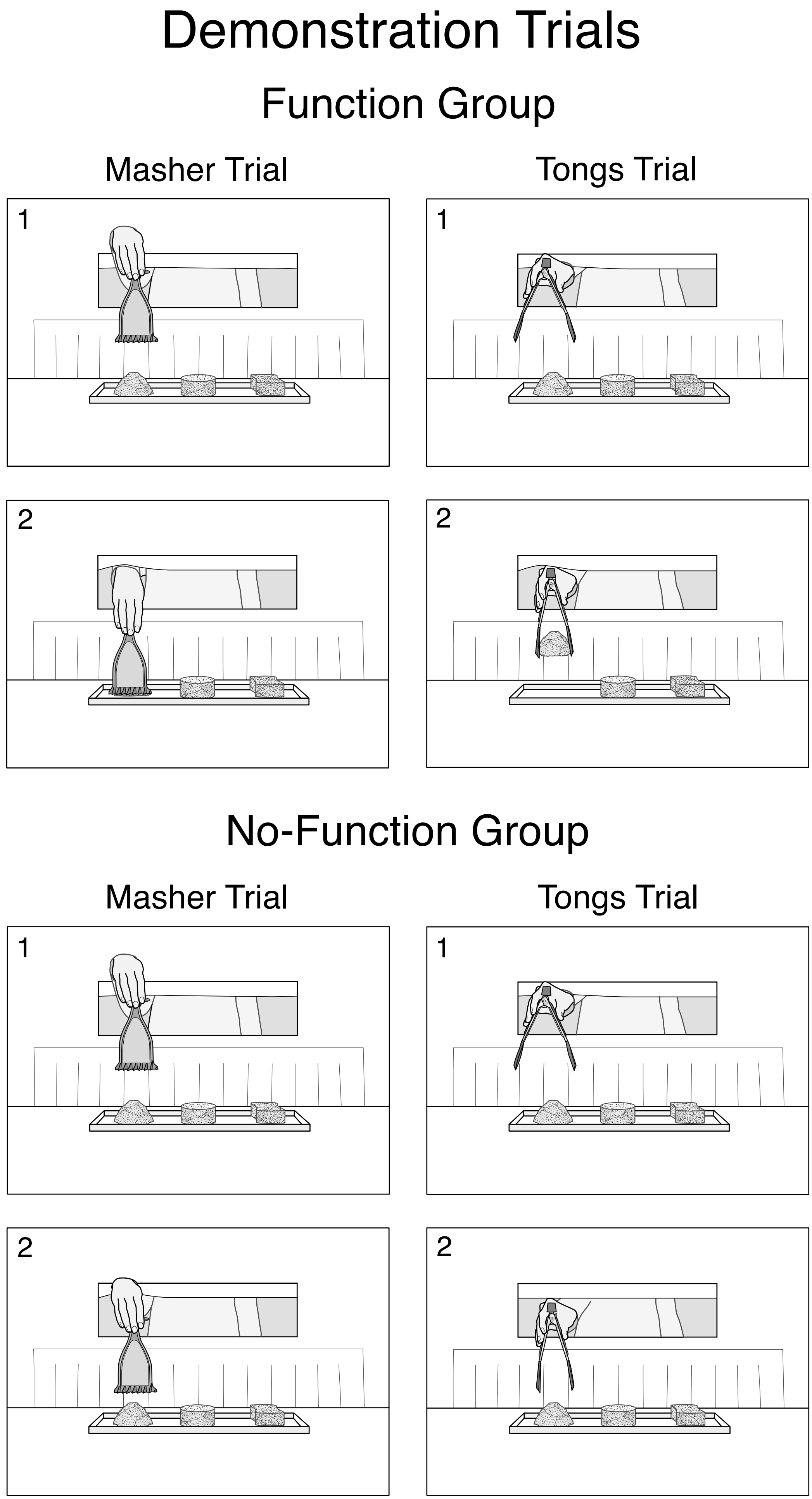
**Figure 1**. Schematic depiction of the events presented in the demonstration trials of the function and no-function groups in Experiment 1. In each trial, the experimenter used the tool to act on (function) or above (no-function) each sponge in turn, going from left to right. Cycles were repeated until the trial ended.

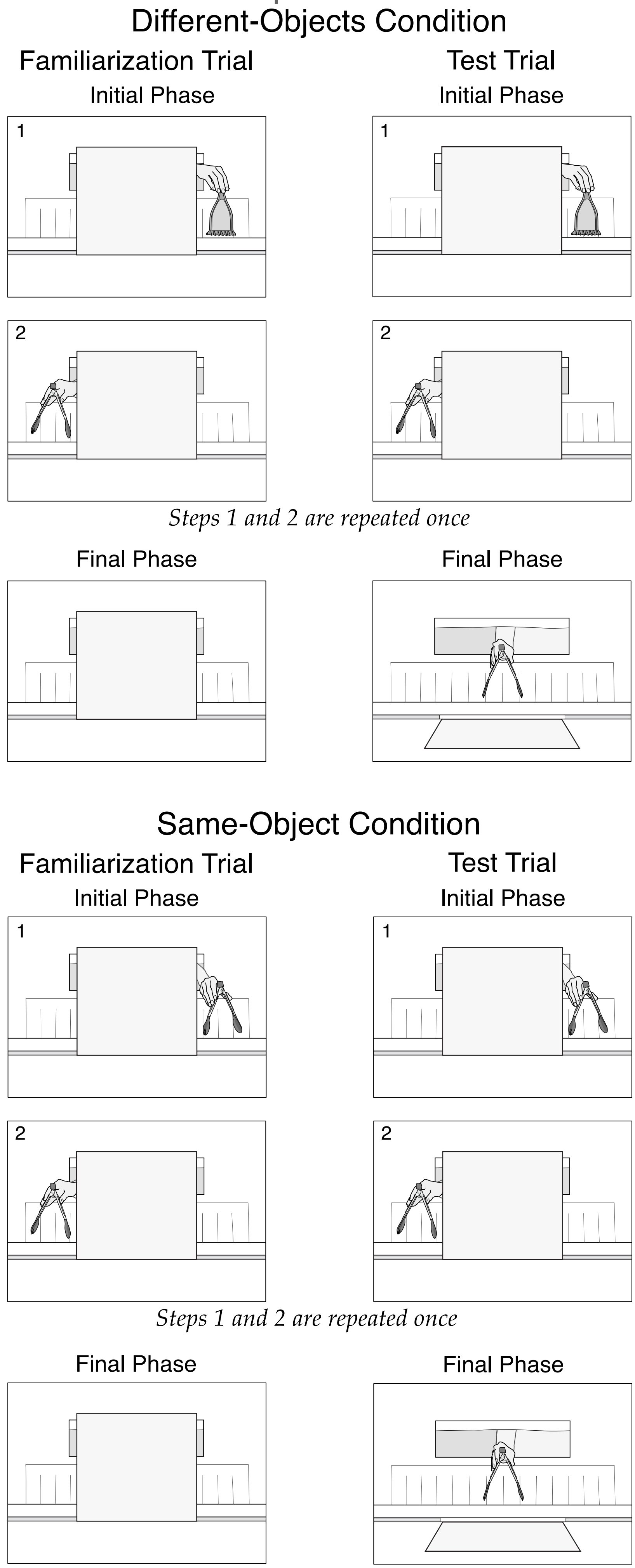
**Figure 2**. Schematic depiction of the events presented in the familiarization and test trials of the different-objects and same-object conditions in Experiment 1.

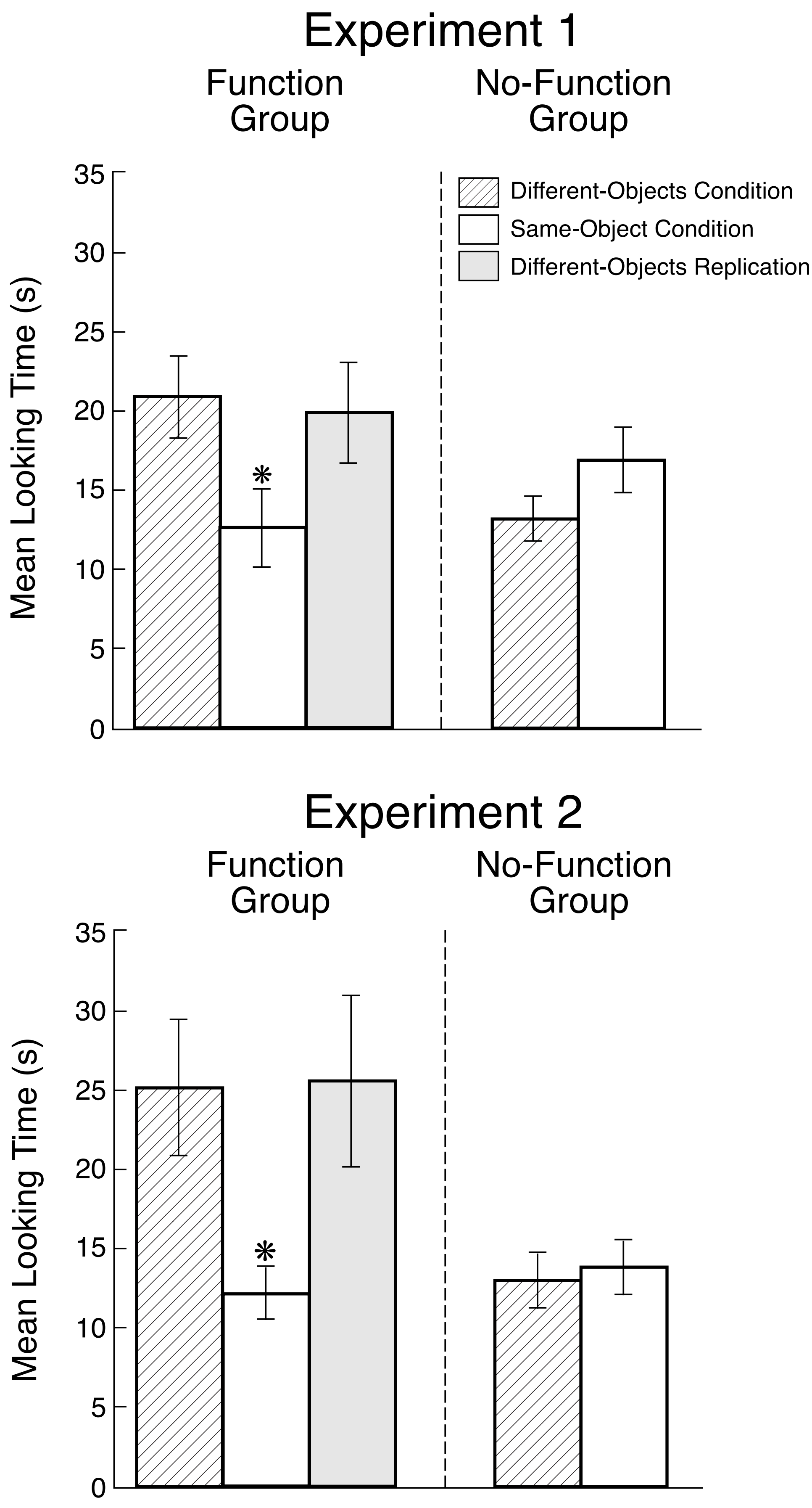
**Figure 3**. Mean looking times in each experiment, by group and condition, during the final phase of the test trial. Errors bars represent standard errors, and an asterisk denotes a significant difference between the conditions ($p$ < .025 or better). Looking times were log-transformed before analysis.

**Figure 4**. Schematic depiction of the events presented in the demonstration trials of the function and no-function groups in Experiment 2. In each trial, the experimenter used the tool to act on (function) or above (no-function) each dry-erase board (marker trial) or play-dough ball (knife trial), going from left to right. Cycles were repeated until the trial ended.

**Figure 5**. Schematic depiction of the events presented in the familiarization and test trials of the different-objects and same-object conditions in Experiment 2.


Demonstration Trials
Function Group
Masher Trial
Tongs Trial
1
1
2
2
No-Function Group
Masher Trial
Tongs Trial
1
1
2
2

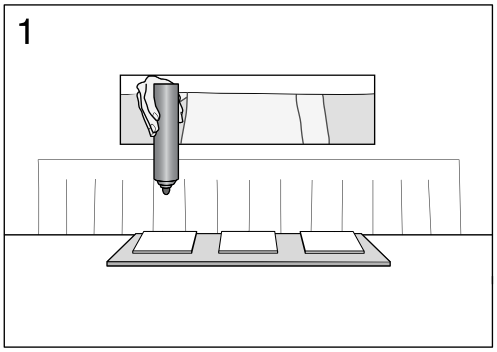

Different-Objects Condition
Familiarization Trial
Test Trial
Initial Phase
Initial Phase
1
1
2
2
Steps 1 and 2 are repeated once
Final Phase
Final Phase
Same-Object Condition
Familiarization Trial
Test Trial
Initial Phase
Initial Phase
1
1
2
2
Steps 1 and 2 are repeated once
Final Phase
Final Phase

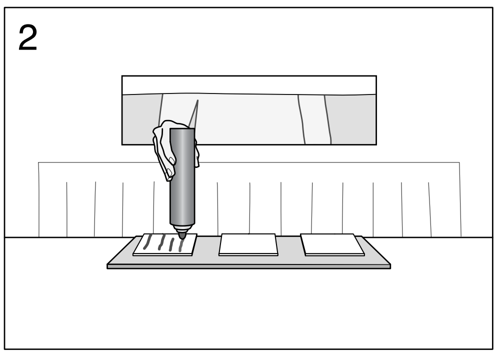

Experiment 1
Function Group
No-Function Group
Mean Looking Time (s)
35
30
25
20
15
10
5
0
Different-Objects Condition
Same-Object Condition
Different-Objects Replication
*
Experiment 2
Function Group
No-Function Group
Mean Looking Time (s)
35
30
25
20
15
10
5
0
*

# Demonstration Trials

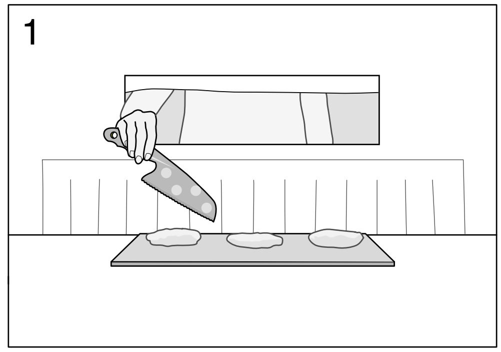
## Function Group

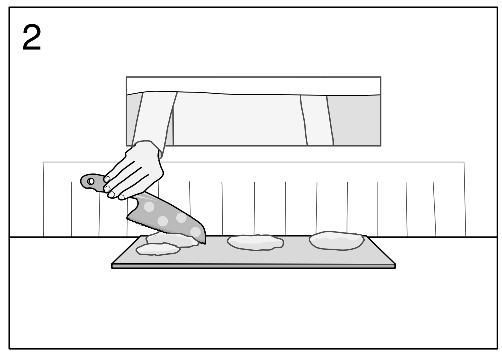
### Marker Trial



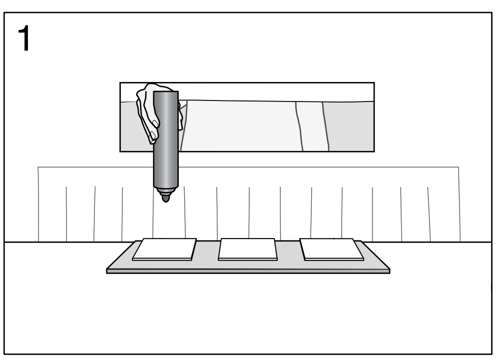

### Knife Trial

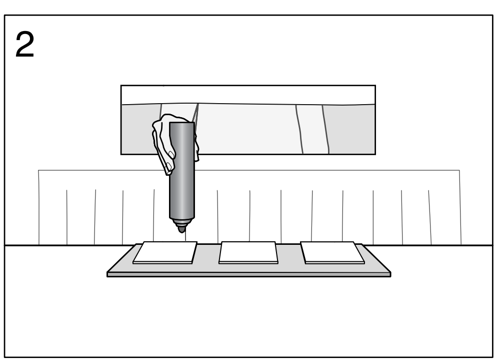


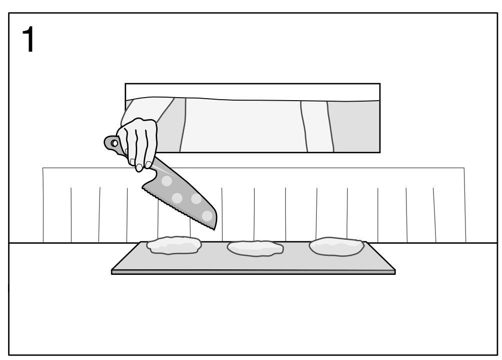

## No-Function Group

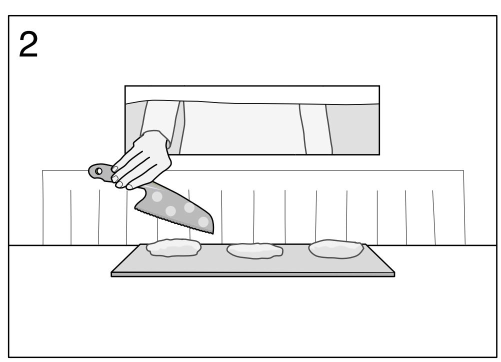
### Marker Trial




### Knife Trial



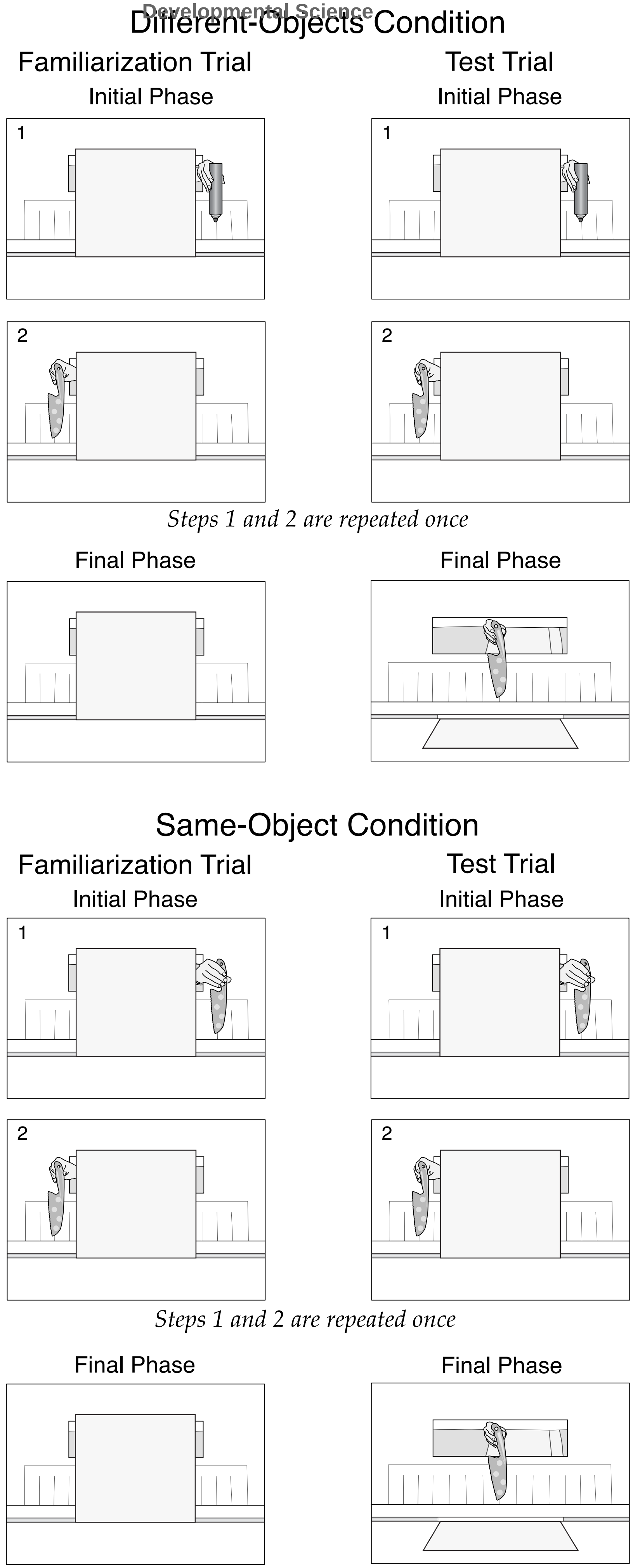

Different-Objects Condition
Familiarization Trial
Test Trial
Initial Phase
Initial Phase
1
1
2
2
Steps 1 and 2 are repeated once
Final Phase
Final Phase
Same-Object Condition
Familiarization Trial
Test Trial
Initial Phase
Initial Phase
1
1
2
2
Steps 1 and 2 are repeated once
Final Phase
Final Phase

Table 1

*Mean looking times (and standard deviations) during the demonstration, familiarization, and test trials, separately per experiment, group, and condition.*

| | Demonstration Trials | Familiarization Trial | | Test Trial | |
|---|---|---|---|---|---|
| | | Initial Phase | Final Phase | Initial Phase | Final Phase |
| **Experiment 1** | | | | | |
| ***Function Group*** | | | | | |
| Different-objects Condition | 50.2 (8.8) | 32.6 (7.5) | 12.2 (8.2) | 33.0 (5.6) | 20.1 (9.0) |
| Same-object Condition | 50.7 (5.4) | 37.0 (2.9) | 13.2 (6.8) | 36.3 (5.4) | 12.6 (8.6) |
| Different-objects Replication | 53.2 (7.6) | 31.9 (7.1) | 10.2 (7.2) | 35.1 (3.6) | 19.8 (11.0) |
| ***No-Function Group*** | | | | | |
| Different-objects Condition | 44.2 (8.0) | 32.1 (6.0) | 12.4 (8.8) | 32.5 (7.9) | 13.1 (4.9) |
| Same-object Condition | 46.8 (6.2) | 32.1 (8.3) | 9.5 (7.1) | 36.1 (5.6) | 16.9 (7.1) |
| **Experiment 2** | | | | | |
| ***Function Group*** | | | | | |
| Different-objects Condition | 42.0 (8.8) | 34.2 (5.8) | 13.3 (7.6) | 34.2 (5.9) | 25.0 (14.9) |
| Same-object Condition | 45.9 (11.1) | 33.1 (4.7) | 11.7 (7.7) | 35.1 (6.4) | 12.1 (5.9) |
| Different-objects Replication | 48.9 (10.3) | 32.5 (8.6) | 9.7 (7.7) | 33.9 (7.8) | 25.5 (18.7) |
| ***No-Function Group*** | | | | | |
| Different-objects Condition | 49.0 (9.9) | 34.5 (6.0) | 11.3 (4.8) | 36.2 (5.6) | 12.9 (6.1) |
| Same-object Condition | 47.2 (11.4) | 35.2 (3.5) | 9.6 (5.9) | 32.9 (8.3) | 13.8 (6.1) |

Note: Values for the demonstration trials were averaged across the two trials. The familiarization and test trials each had an initial and a final phase, and looking times during the two phases were computed separately. Looking times were log-transformed before analysis.