



Naming guides how 12-month-old infants encode and remember objects

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A foundation of human cognition is the flexibility with which we can represent any object as either a unique individual (my dog Fred) or a member of an object category (dog, animal). This conceptual flexibility is supported by language; the way we name an object is instrumental to our construal of that object as an individual or a category member. Evidence from a new recognition memory task reveals that infants are sensitive to this principled link between naming and object representation by age 12 mo. During training, all infants ($n = 77$) viewed four distinct objects from the same object category, each introduced in conjunction with either the same novel noun (Consistent Name condition), a distinct novel noun for each object (Distinct Names condition), or the same sine-wave tone sequence (Consistent Tone condition). At test, infants saw each training object again, presented in silence along with a new object from the same category. Infants in the Consistent Name condition showed poor recognition memory at test, suggesting that consistently applied names focused them primarily on commonalities among the named objects at the expense of distinctions among them. Infants in the Distinct Names condition recognized three of the four objects, suggesting that applying distinct names enhanced infants' encoding of the distinctions among the objects. Infants in the control Consistent Tone condition recognized only the object they had most recently seen. Thus, even for infants just beginning to speak their first words, the way in which an object is named guides infants' encoding, representation, and memory for that object.

infants | language | learning | memory | naming

The link between language and our representations of individuals and categories is well established in children and adults; the words we use to describe objects and people, as either unique individuals (e.g., “Jane likes chess”) or category members (e.g., “the girl likes chess”), guide our inductive generalizations and causal attributions (1–3). At issue is how, and how early, this link between language and representation is established.

Although it is theoretically possible that forming such a link would require that infants had first acquired a robust set of category names and individual names, the evidence suggests otherwise. By age 12 mo, before infants produce many words, principled links between how objects are labeled and how infants represent them are already apparent. For example, when infants view a series of different objects (e.g., a dog, a horse, a duck, and a lion) that are named consistently with the same novel noun, they successfully form an inclusive object category (e.g., “animals”) (4–10). In contrast, if each object is named with a distinct novel noun, infants infer that the objects belong to different object categories (9, 11–13). Thus, infants are sensitive to whether and how objects are named. Furthermore, this sensitivity supports not only object categorization but also object individuation. Hearing distinct names for objects facilitates infants' ability to represent and track multiple objects even when the objects are hidden from view (11, 14–17).

Perhaps the most striking evidence for the influence of naming on object individuation comes from infants' ability to distinguish among faces of individual nonhuman primates. At age 6 mo, infants successfully distinguish individual nonhuman primate faces, but by 9 mo, they fail to do so; their capacity for individuating these faces has diminished. However, if infants hear distinct names applied to a set

of different nonhuman primate faces during this developmental period, they retain the ability to individuate among them.

To demonstrate this, researchers created a picture book featuring six distinct monkey faces, one per page, providing either a distinct name for each face (e.g., “Louis,” “Jamar”) or the same name for all faces (e.g., “monkey”) (18). Parents read the picture book frequently to their infants starting at 6 mo of age. At 9 mo, all infants were invited to the laboratory to assess their ability to distinguish among new, previously unseen monkey faces. Infants trained on the consistently applied name failed to distinguish among new individual monkey faces; however, infants trained on the distinct names successfully discriminated among new faces.

This effect of naming on individuation has been observed for other object categories, including familiar (e.g., strollers) and novel categories (19, 20). Thus, naming category members with distinct but not consistent names supports infants' ability to distinguish among novel members of that category.

These effects, coupled with the powerful evidence that consistently applied names promote categorization, offer strong evidence that language affects infants' conceptual representations of objects. But the mechanism by which this occurs remains unclear: *how* does naming influence infants' representations of objects?

We propose that naming influences how infants encode an object in memory. Specifically, we propose that in the context of consistently applied names, infants focus on and encode commonalities among a set of objects, facilitating object categorization, whereas in the context of distinct names applied to each

Significance

Encoding objects in memory and recalling them later is fundamental to human cognition and emerges in infancy. Here, using a new recognition memory paradigm, we show that the way an object is named, either as a unique individual or as a member of a category, is instrumental in 12-month-old infants' encoding of and memory for that object. When the same name is applied consistently to a set of objects, infants encode primarily their commonalities. In contrast, when a unique name is applied to each object, infants encode each object's unique features. Thus, even as infants begin to produce their first words, a single naming event exerts powerful, nuanced effects on the fundamental cognitive processes of object representation and memory.

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individual, infants focus more on the distinguishing features of each object, facilitating object individuation.

If naming guides infants' conceptual representations of objects as either individuals or members of categories, then this should be reflected in infants' memory. If hearing the same name applied consistently across objects directs infants' attention to commonalities among them, this should concomitantly diminish infants' ability to distinguish these objects from other members of the same category. In contrast, if hearing distinct names directs infants' attention to differences among the objects, this should serve infants well in discriminating these individual objects from other members of the category.

Experiment

To test this prediction, we developed a new task to assess whether infants' encoding of objects in memory changes as a function of the way in which those objects are named (Fig. 1). We focused on infants between 11.5 and 12.5 mo of age ($n = 77$, $M = 11.90$, $SD = 0.31$) (21). First, in a training period, all infants viewed a series of four novel objects drawn from the same object category. Infants were randomly assigned to one of three conditions: in the Consistent Name condition, each object was paired with the same novel noun (e.g., "Look at the boff!"), in the Distinct Names condition, each object was labeled with a unique novel noun (e.g., "Look at the boff/arg/dohv/etch"), and in the Consistent Tone condition, each object was paired with the same sine-wave tone sequence. Because tone sequences, unlike names, fail to facilitate infants' categorization (4, 22–24), this served as a control condition, assessing infants' baseline recognition memory.

To determine whether naming influenced infants' representations of the objects, we then evaluated the infants' recognition memory for the training objects. Specifically, we assessed their ability to distinguish each training object from a new category member that they had not seen during training. On each of four test trials, the infants saw one previously viewed training object presented side-by-side with a new member of the object category. These were presented in silence. If infants recognize the training object, they should prefer to look at the new object (25, 26).

Critically, if infants in the Consistent Name condition encoded commonalities among the training objects at the expense of their individuating features, then they should have difficulty distinguishing these training objects from new category members presented at test. In contrast, if infants in the Distinct Names condition encoded each object as a distinct individual, focusing on the object's unique features, then they should readily distinguish the training objects from the new category members presented at test.

Moreover, we predicted that these differences between conditions should appear only for the objects presented in the last two trials of the Training Phase. We reasoned as follows. Training Trial 1 is identical for infants in the Consistent Name and Distinct Names conditions; because infants in both conditions see an object paired with a novel name, no differences should emerge. On Training Trial 2, we also predicted no differences between naming conditions; infants in both conditions should encode Training Object 2 broadly to compare it with their memory of Training Object 1. Comparison is instrumental to identifying both similarities (e.g., for infants in the Consistent Name condition) and differences (e.g., for infants in the Distinct Names condition) (27, 28). Moreover, with two consistently named exemplars, infants successfully begin to identify objects' commonalities (4, 29, 30). However, by Training Trials 3 and 4, infants' encoding of the training objects should vary as function of condition. Infants in the Consistent Name condition should focus on commonalities between these training objects and those seen previously; in contrast, infants in the Distinct Names condition should focus on features that distinguish each object from the others. Finally, infants in the Consistent Tone condition should show a straightforward recency effect, with strong memory for the most recently seen training object and diminishing ability to distinguish among less recently viewed objects (26).

To evaluate these predictions, we developed a stringent test of recognition memory (Fig. 1). In the Test Phase, we presented the training objects in reverse order. Thus, the final object presented during training (on Training Trial 4) appeared in the first test trial (Test Trial 1) and vice versa. If infants in the Consistent Name condition encoded the final training object primarily as a



Fig. 1. During the Training Phase, all infants viewed four objects, presented one at a time in a random order. Objects were paired with either a Consistent Name, Distinct Names, or a Consistent Tone. In four silent Test Trials, all infants viewed each of the training objects paired with a new object from the same category. In the Test Phase, the training objects were presented in reverse order from the Training Phase.

category member, they should have difficulty distinguishing it from a new member of the same object category, even when tested on it immediately afterward. As a result, they should look equally to the two objects at test. In contrast, if infants in the Distinct Names condition encoded the final training object's unique features, they should readily recognize that particular object at test and so should look more to the novel object.

Results

As predicted, the infants' memory for the training objects varied as a function of condition (Fig. 2) (21). A linear mixed-effects model with condition (Consistent Name vs. Distinct Names vs. Consistent Tone) and test trial (Trials 1 to 4) as fixed effects (details in *Methods*) revealed an interaction between condition and test trial: $\chi^2(2) = 6.02, P = 0.049$.

We then examined our critical prediction, that the Consistent Name and Distinct Names conditions would yield different patterns of memory across trials. Here a linear mixed-effects model yielded an effect of test trial ($\beta = -0.051, SE = 0.021, P = 0.015$) modified by the predicted interaction between condition and test trial ($\beta = 0.081, SE = 0.030, P = 0.0068$). Thus, the infants' memory for the objects differed in accordance with how the objects were named.

To characterize the performance in each of these conditions, we next compared the performance on each trial against chance, beginning with Test Trials 1 and 2 (between-condition comparisons are shown in *SI Appendix*). Infants in the Distinct Names condition successfully recognized the training object in both Test Trial 1 and Trial 2, looking more to the novel object in Test Trial 1 [$M = 0.58, SD = 0.07, t(25) = 5.41, P < 0.001$] and Test Trial 2 [$M = 0.55, SD = 0.07, t(25) = 3.53, P = 0.002$]. In contrast, infants in the Consistent Name condition failed to make this individual-level distinction in either trial, performing at chance levels in Test Trial 1 [$M = 0.52, SD = 0.06, t(23) = 1.32, P = 0.20$] and Test Trial 2 [$M = 0.50, SD = 0.10, t(24) = 0.08, P = 0.93$]. Thus, by the end of training, the naming conditions exerted divergent effects on memory; infants in the Distinct Names condition successfully encoded the objects' individuating features, while those in the Consistent Name condition focused primarily on their commonalities.

Also as expected, infants in the Consistent Name and Distinct Names conditions performed similarly on Test Trials 3 and 4. On Test Trial 3, infants in both conditions preferred the novel object [Consistent Name: $M = 0.54, SD = 0.10, t(23) = 2.07, P = 0.05$; Distinct Label: $M = 0.56, SD = 0.11, t(24) = 2.74, P = 0.01$]. On Test Trial 4, infants in both conditions performed at chance levels [Consistent Name: $M = 0.55, SD = 0.14, t(23) = 1.62, P = 0.12$; Distinct Label: $M = 0.50, SD = 0.14, t(23) = 0.002, P = 0.99$]. This pattern of performance is consistent with our prediction that infants' encoding of and attention to the first two training objects would be identical across conditions.

Finally, we compared the performance in each naming condition with the performance in the Consistent Tone condition, which provided a baseline for infants' recognition memory. As expected, performance in the Consistent Tone condition was intermediate between that in the Consistent Name and Distinct Names conditions (Fig. 2). A linear mixed-effects model comparing the Consistent Tone and Consistent Name conditions revealed a marginal interaction between condition and test trial ($\beta = -0.054, SE = 0.032, P = 0.09$). Comparing the Consistent Tone with the Distinct Names condition yielded a nonsignificant interaction with test trial ($\beta = -0.023, SE = 0.032, P = 0.48$).

To capture infants' pattern of performance across trials in the Consistent Tone condition, we conducted planned comparisons against chance. Infants successfully recognized only the training object they had most recently seen [Test Trial 1: $M = 0.57, SD = 0.11, t(24) = 3.15, P = 0.004$] and failed to recognize the training object on any subsequent test trial ($P > 0.25$ for all). In contrast, recall that infants in the Consistent Name condition failed to remember even this most recent exemplar, and infants in the Distinct Names condition successfully recognized all but one of the training objects.

These results document a striking effect of naming on infants' conceptual representations: labeling objects with consistent or distinct names influences how infants encode those objects and represent them in memory. Providing distinct names enabled infants to successfully discriminate those objects from others of the same category; infants in the Distinct Names condition did so on 3 of 4 test trials. Providing a consistent name had a different effect: infants in the Consistent Name condition failed to distinguish the individuals presented during training from others of the same

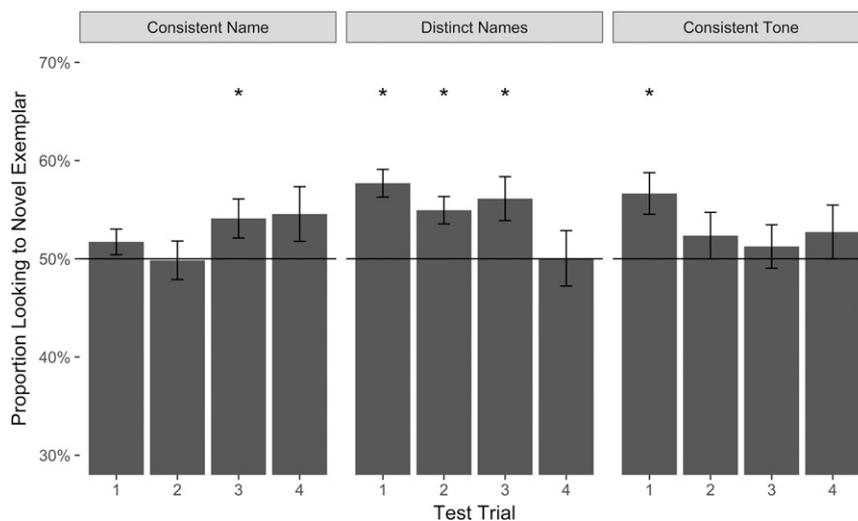


Fig. 2. Infants' proportion looking to the novel exemplar in the Consistent Name, Distinct Names, and Consistent Tone conditions for Test Trials 1 to 4. Error bars represent ± 1 SEM. Significantly novelty preferences ($P < 0.05$) are marked by an asterisk. In addition, differences between the Distinct Names and Consistent Name conditions emerged on Test Trials 1 and 2 ($P < 0.05$) and between the Consistent Name and Consistent Tone conditions on Test Trial 1 ($P = 0.05$) (*SI Appendix*).

category, even if they had seen that object only moments before. Finally, providing a consistent tone sequence revealed a different pattern: infants in the Consistent Tone condition successfully recalled the most recently seen exemplar but no others.

Discussion

Our findings reveal a powerful and sophisticated effect of language on cognition in infancy: the way in which an object is named, as either a unique individual or a member of a category, influences how 12-mo-old infants encode and remember that object. Hearing a consistent name applied to a set of objects focuses infants on the commonalities among them, while hearing distinct names applied to the same objects focuses infants on the uniqueness of each object. Our findings demonstrate that for infants as young as 12 mo of age, whether and how an object is named has rapid and conceptually precise consequences on their representation of that object. Moreover, these results reveal that even a single naming episode can have a lasting impact, influencing how infants encode that object, represent it in memory, and remember it later.

This work reveals a mechanism underlying the well-documented advantage conferred by consistent naming on infant object categorization (4, 9, 10, 22, 24, 31). There is now little doubt that naming a set of objects with the same noun invites infants to form a category (10, 32). Here we show that this invitation leads infants to focus on the commonalities among like-named objects and occurs at the expense of representing the unique features of each individual object.

Previous work has also shown that providing distinct names for objects does not support categorization (6, 9, 13) but does facilitate object individuation (18–20). Here we show that these effects stem from a focus on distinctions among objects, yielding a stronger representation of each unique individual and supporting infants' subsequent recognition of those individuals. Thus, this evidence supports a nuanced and powerful role for object naming in infants' encoding and conceptual representations of individual objects.

Together, our results reveal a rapid influence of naming on infants' online object processing. This influence occurs in the course of a single naming episode without requiring months of training (18–20). However, even these brief naming episodes have lasting consequences for infants' representations of the named objects. This suggests that naming may play a ubiquitous role in infants' everyday learning, supporting the capacity to represent objects flexibly as either distinct individuals or members of an object category.

This evidence opens new avenues for future investigations. First, because the current experiment focused exclusively on novel nouns, how familiar nouns (e.g., "Fido" or "dog") influence infants' object representations remains an open question. Addressing this question should also shed light on current debates in research with adults (33–36). Second, although the present work focuses on infants at 12 mo, it will be important to specify the effects of naming on infants' object representations throughout the first year of life. Naming utterances support the establishment of object categories consistently throughout the first year, beginning as early as 3 mo of age (23, 24); however, whether naming confers its benefits via the same mechanisms throughout this period remains unclear. In our view, the early advantage of naming likely derives from general attentional factors, with the more sophisticated labeling effects documented here emerging by the close of the first year (37). Finally, additional research is needed to assess how infants recruit other kinds of words, including proper names, when constructing object representations (38, 39). Overall, the goal is to gain a richer appreciation of how naming influences conceptual representations from infancy through adulthood.

Materials and Methods

Participants. Seventy-seven infants (40 females, 37 males) age 11.5 to 12.5 mo from predominantly college-educated, white families in the greater Chicago area participated in the experiments. All infants were monolingual and acquiring English with less than 30% exposure to a second language, as estimated by parent report. Sample size varied slightly by condition because we continued running participants until we obtained at least 24 infants providing data for each of the four test trials in the Distinct Label ($n = 27$), Consistent Name ($n = 25$), and Consistent Tone ($n = 25$) conditions. This sample size was derived from a power analysis assuming $\alpha = 0.05$ and an effect size of $d = 1.32$, which reflects the strength of 12-mo-olds' preference for a novel object on an immediate memory test (40). To accommodate the longer delays between some of our learning and test trials, we aimed for 99% power, yielding a target sample size of 23 infants per cell, rounded up to 24 for counterbalancing. This sample size also yields 99% power for the comparison between labeling conditions ($d = 1.35$) reported in ref. 20.

Thirteen additional infants were excluded from our analysis for failing to contribute at least three usable test trials ($n = 7$), looking for <25% of the Training Phase ($n = 2$), or technical difficulties ($n = 4$). In addition, 13 test trials were excluded from the analysis when infants failed to look for a minimum of 5 s during the test trial, did not look to both objects during the test trial, or did not look for a minimum of 5 s at the familiar object during its training trial. The latter requirement ensured that we tested infants' memory only for objects that they spent substantial time encoding during training.

Visual Stimuli. Infants viewed photos of stuffed animals, similar to the animal toys used in previous work (10). All images were readily understood by adults to represent real animals (i.e., not imaginary creatures).

Auditory Stimuli. Naming phrases were recorded by a female native English speaker in a soundproof booth and lasted for $\sim 3,800$ ms. Each naming phrase contained two sentences and repeated the name twice (e.g., "Look at the boff! Do you see the boff?"). For the Distinct Names condition, nouns were selected to be phonetically distinct (i.e., "arg," "dohv," "boff," "etch"), ensuring that infants could recognize them as different words. Sine-wave tone sequences were matched in duration and average pitch to the naming phrase used in the Consistent Name condition.

Procedure. The infant was seated on a caregiver's lap ~ 120 cm from a large screen, 115 cm high \times 154 cm wide. Visual stimuli were projected onto the screen, and auditory stimuli were played from speakers hidden below the screen. The left and right positions of the objects on the screen were separated by 35 cm. Caregivers wore opaque sunglasses during the task and were instructed not to talk to the infants or influence their behavior in any way, except to recenter the infants on their lap if necessary.

Infants were first shown an attention-grabbing stimulus, a colorful, spinning circle that alternated sides of the screen to accustom infants to looking to both sides. Infants then began training. Training was highly similar to that done in previous object categorization studies (6, 10, 13). Infants viewed a series of four objects, presented one at a time for 20 s each on alternating sides of the screen, with the starting side counterbalanced across infants. The training and test objects were selected randomly for each infant. Across conditions, the relevant auditory stimulus was always played twice for each object, after trial onset and 10 s into the trial.

After training, infants saw an attention-grabbing stimulus presented in the center of the screen. Their looking was coded live by a research assistant. When they looked to the attention-getter for 500 ms, the test trial began. This was repeated before each test trial.

During the Test Phase, the infants viewed four test trials. Each trial featured two objects presented side by side: one that infants had already seen during training and one that was new to infants. These objects were presented for 20 s or until infants accumulated 10 s of looking; in line with past work in this paradigm, only the first 10 s of each infant's looking were analyzed (6, 24). The novel object's presentation side alternated between trials and was counterbalanced across infants.

As noted above, the familiar objects at test were presented in the reverse order as they were seen during training. Because the difference between conditions is expected to emerge only for the final two training objects, this design provided the best test of the predicted effect. Thus, the first two test trials represent the critical test of the hypothesis.

Coding. Infants' looking during the Training Phase was coded to ensure that they were attending to the objects. All coding was done offline using frame-by-frame

software (41). Infants' overall looking time during training did not differ across the Consistent Name ($M = 59.2$ s, $SD = 12.3$) and Distinct Names ($M = 55.6$ s, $SD = 11.6$) conditions [$t(50) = 1.10$, $P = 0.28$]; however, looking was significantly higher in these conditions than in the Consistent Tone condition ($M = 50.5$ s, $SD = 11.3$; $t(75) = 2.40$, $P = 0.035$). While infants apparently found tones less engaging than language, their behavior still demonstrated fairly robust attention during training (~ 12.5 s per object). Moreover, there was no effect of looking time on novelty preference in this condition ($\beta = -0.00004$, $SE = 0.004$, $P = 0.99$), suggesting that this difference between groups did not substantially affect our results.

Infants' looking time at test served as our dependent measure. We calculated a novelty preference score for each test trial (time looking at novel object/time looking at both objects). Looking was coded offline by trained coders, blind to condition. A second coder recoded 27% of the infant videos; reliability between the coders was high (Pearson's $r = 0.90$, $P < 0.0001$). Proportions were arcsin-root transformed for analysis with linear models. All data are available at <https://osf.io/5wnqr/>.

Modeling Approach. All analyses were performed in R (42). To analyze how performance changed across test trials, we constructed a linear mixed-

effects model in lme4 (43, 44). In Experiment 1, this included fixed effects for condition (dummy coded) and test trial (coded as a linear polynomial contrast), as well as their interaction. We also included random effects for participant and the target image. To assess significance, we used the Satterthwaite approximation for degrees of freedom as recommended to minimize type I error (45) and implemented in the lmerTest package (46) and likelihood ratio tests for multiple-df tests.

Data Availability. Anonymized data have been deposited in the Open Science Framework database (<https://osf.io/378tn/>). All study data are included in the text and *SI Appendix*.

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