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In the Infant's Mind's Ear: Evidence for Implicit Naming in 18-Month-Olds

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Abstract

Do infants implicitly name visually fixated objects whose names are known, and does this information influence their preference for looking at other objects? We presented 18-month-old infants with a picture-based phonological priming task and examined their recognition of named targets in primed (e.g., dog-door) and unrelated (e.g., dog-boat) trials. Infants showed better recognition of the target object in primed than in unrelated trials across three measures. As the prime image was never explicitly named during the experiment, the only explanation for the systematic influence of the prime image on target recognition is that infants, like adults, can implicitly name visually fixated images and that these implicitly generated names can prime infants' subsequent responses in a paired visual-object spoken-word-recognition task.

Keywords

implicit naming, priming, visual-world paradigm, cross-modal priming

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In this study, we investigated whether infants can implicitly name visually fixated images: If an infant is shown a picture of a cat, is the word *cat* implicitly generated in the infant's mind's ear? In addition, we studied whether these implicitly generated labels can guide an infant's eye movements toward other objects with similar-sounding names (e.g., *cup*, which begins with the same consonant sound as *cat*) in a visual-world task. Evidence for implicit generation of the names of visually fixated images would further researchers' understanding of the processes underlying infants' integration of auditory and visual information in speech and their processing of the visual world, and would clarify the lexical categories available to the developing infant.

Research on language processing by infants is usually based on the assumption that object identification in a visual-world task proceeds from hearing the object's name and then generating a semantic representation that can be matched to a visually presented image (Swingley & Fernald, 2002). An alternative analysis in the case of objects whose names are known is that infants implicitly generate the name of a visually fixated image and match this internally generated label to the name presented during the visual-world task. Implicitly generated labels could also guide early thematic associations between the labels of objects that are often physically proximate but not overtly labeled (e.g., pen and paper). Implicit naming may further highlight the taxonomic relation between objects through their shared capacity to elicit a single common label (e.g., "dog").

Meyer, Belke, Telling, and Humphreys (2007; see also Meyer & Damian, 2007; Jescheniak & Levelt, 1994; Jescheniak, Schriefers, Garrett, & Friederici, 2002) provided compelling evidence that adults are capable of implicit generation of the names of visually fixated images. Participants were initially presented an image (the prime image) in silence (e.g., that of a boy). Next, images of four objects were presented simultaneously. One of these four images had a label that was a homophone of the prime image (e.g., "buoy"). The images that were homophonically related to the prime images attracted participants' gaze more often than images with labels that were phonologically unrelated to the prime images. As neither the prime image (boy) nor the homophone competitor (buoy) had been named during the trial, the only explanation for participants preferring the homophone competitors is that they internally generated names for the visually presented images (both primes and homophone distractors) and that these names led to a preference for the images with homophone labels. These findings show that adults implicitly generate the names of visually fixated images, and that such implicit naming can influence subsequent eye fixations.

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In the study reported in this article, we examined whether infants, like adults, implicitly generate the names of visually fixated images, using an experimental paradigm similar to that used by Meyer et al. (2007). As the infant lexicon is considerably smaller than the adult lexicon, we could not investigate priming using homophone images. However, we could test whether a prime image influences an infant's response to an image with a label that begins with the same phoneme as the prime label (e.g., ball-book).

Note that in Meyer et al. (2007), the prime image was presented to participants in silence. This part of the experimental design is crucial to the study's conclusion, as the observed priming effects can be explained only by the participants' implicit generation of the prime images' names, which then primed a subsequent preference for fixating the homophonically related images. Thus, in our study, we presented infants with the prime images in silence, and compared infants' responses to subsequent presentations of phonologically related and unrelated words and images. Any systematic difference between responses to related and unrelated images could be explained only by concluding that infants implicitly generated the labels for the prime images and that these labels then primed their eye movements to the phonologically related target images.

Method

Participants

The participants were 27 infants approximately 18 months in age (M = 17.84 months, range = 17.06–18.73). Eight additional infants were tested but excluded from the study because of fussiness or experimenter error. All the infants came from homes where British English was the primary language in use.

Procedure

During the experiment, infants sat on their caregiver's lap 80 cm away from a television screen. Two cameras mounted directly above the pictures on the screen recorded infants' eye movements. All images measured 36 cm in length by 24 cm in height. Image pairs were positioned 15 cm apart. Auditory stimuli were presented through centrally located loudspeakers above the screen. Speech stimuli were produced by a female speaker of British English in an enthusiastic, child-directed manner.

Infants were presented with 16 trials each. Trials began with the presentation of a familiar object (i.e., the prime image) at a central location on the screen for 1.5 s. The prime image was presented in silence. The offset of the prime image was followed by a blank screen for 200 ms, and then two side-by-side images of familiar objects (i.e., the target and distractor images) for 2,050 ms. Fifty milliseconds after the onset of these two images, infants were presented with an auditory label for the target image in citation form. Therefore, the two images continued on screen for 2,000 ms after the onset of the auditory label. In half of the trials (primed trials), the label the infants heard (e.g., "cup") began with the same consonant as the unheard label for the prime image (e.g., "cat"). In the other half of the trials (unrelated trials), the heard label was phonologically unrelated to the label for the prime image (see Fig. 1).

Labels for the target, prime, and distractor images were semantically and associatively unrelated according to the Edinburgh Word Association Thesaurus (Kiss, Armstrong, Milroy, & Piper, 1973) and Birkbeck Word Association Norms (Moss & Older, 1996). The only attested relationship between targets and primes in primed trials was the phonological relationship between the unheard prime label and the heard target label. There was no relationship between the primes and targets in unrelated trials. The distractor image was never labeled. Infants saw each image only once during the experiment. A given target and distractor were yoked and appeared in the primed and unrelated conditions with equal frequency (see Table 1). Primes were counterbalanced, so the same prime image appeared with equal frequency in primed and unrelated trials. Targets were positioned on the left and on the right side of the screen with equal frequency in primed and unrelated trials.

Scoring

A digital video scoring system assessed visual events on a frame-by-frame basis (every 40 ms). This technique enabled blind coding of every eye fixation. A second well-trained

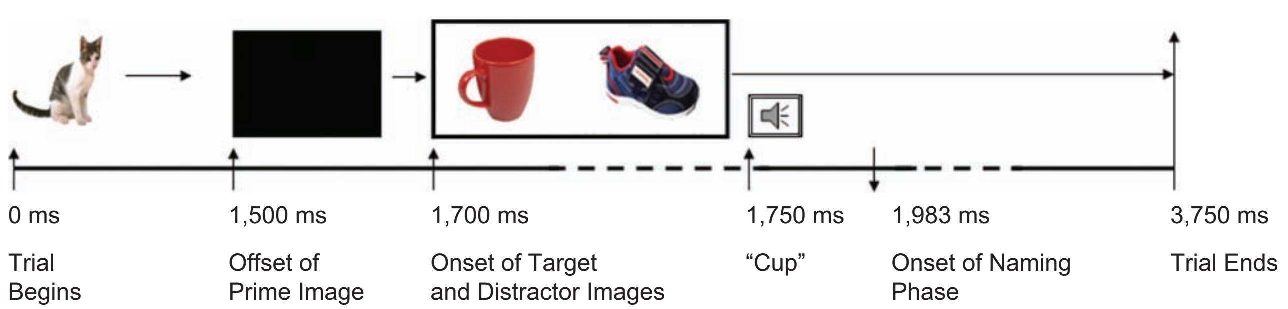

Fig. 1. Time line of a typical trial. Each trial included the following displays, in sequence: the prime (1,500 ms), a blank screen (200 ms), and two images (one target and one distractor) on the same screen (2,050 ms). An auditory clip was played 50 ms after the onset of the final pair of images, and then the naming phase began.

Table 1. Target-Distractor Pairings and Prime Images in Primed and Unrelated Trials

		Prime image	
Target label	Distractor label	Primed trials	Unrelated trials
Ball (97%)	Truck (61%)	Bee (61%)	Comb (30%)
Bear (52%)	Duck (91%)	Boat (62%)	Pen (51%)
Bike (70%)	Hand (76%)	Bowl (57%)	Cat (93%)
Bird (88%)	Sheep (70%)	Bib (75%)	Cake (55%)
Book (95%)	Foot (70%)	Bath (93%)	Cow (85%)
Boot (53%)	Fork (44%)	Bed (83%)	Pig (78%)
Bus (98%)	Sock (91%)	Bin (70%)	Deer (11%)
Car (96%)	Eye (85%)	Cake (55%)	Bed (83%)
Coat (78%)	Tree (66%)	Cow (85%)	Bin (70%)
Cot (71%)	Train (66%)	Comb (30%)	Bee (61%)
Cup (79%)	Shoe (98%)	Cat (93%)	Teeth (75%)
Dog (98%)	Hen (60%)	Door (87%)	Boat (62%)
Doll (60%)	Chair (81%)	Deer (11%)	Bib (75%)
Peas (47%)	Hat (88%)	Pig (78%)	Bath (93%)
Pup (20%)	Mouse (54%)	Pen (51%)	Door (87%)
Toe (69%)	Key (73%)	Teeth (75%)	Bowl (57%)

Note: Numbers in parentheses refer to the percentage of 18-month-olds who know the words according to Communicative Development Inventory (CDI, a British adaptation of the MacArthur CDI, Fenson et al., 1993) reports (Hamilton, Plunkett, & Schafer, 2000).

coder evaluated the data from 10% of the participants (correlation $r = .99$ between the two coders' evaluations).

We analyzed only eye movements launched between 233 and 2,000 ms after the onset of the target word (Canfield & Haith, 1991; Haith, Hazan, & Goodman, 1988; Swingley, Pinto, & Fernald, 1999), and used two exclusion criteria for analyses. First, we excluded trials in which infants fixated either only the target or only the distractor (30% of the trials) throughout the trial. A second less stringent analysis excluded trials in which the infant fixated only the distractor throughout the trial (10% of trials). With these exclusion criteria, we attempted to eliminate trials in which infants were not on task. We assumed that infants who exclusively fixated the distractor throughout the trial were not on task. The more stringent criterion of eliminating trials on which either only the target or only the distractor were fixated was based on the same rationale. Coded video frames were used to determine our measure of the *proportion of target looking*, which we calculated by dividing the total amount of time infants spent looking at the target by the total amount of time they spent looking at both the target and the distractor (i.e., time looking at the target plus time looking at the distractor).

We also report here an alternative index of infants' preference for the target image, which we based on the amount of time infants took to switch their gaze either from the distractor to the target image or from the target to the distractor image upon hearing the target label. A rapid change in gaze after this point is generally interpreted as a measure of infants' perception of a mismatch between the picture currently fixated and the heard label.

Results and Discussion

Figure 2 shows that infants' preference for the target was primed, or facilitated, by the presentation of a phonologically related prime image (*primed* trials) compared with an unrelated prime image (*unrelated* trials). Infants looked significantly longer at the target in primed trials than in unrelated trials, $t(26) = 2.65$, $p = .013$, $d = 0.79$. This effect was also significantly different by items, $t(15) = 2.60$, $p = .02$, $d = 0.62$. This pattern was maintained throughout the course of the trial (see Fig. 3). This analysis used the more stringent exclusion criterion: Only trials in which infants fixated both target and distractor pictures were considered. Repeating the analysis but excluding trials in which infants fixated only the distractor picture (i.e., including trials in which infants fixated both the target and the distractor in the same trial) led to a very similar pattern of results: Infants looked longer at the target in primed trials than in unrelated trials, $t(27) = -2.16$, $p = .03$, $d = 0.59$.

As the prime image was presented in silence during each trial, the systematic priming of preference for the phonologically related target image (i.e., the image that had a label phonologically related to the prime label) can be attributed only to infants implicitly generating the label for the prime image. Note that the prime image itself did not cause the observed difference in target preference between primed and unrelated trials. Across infants, a given prime image and a given target and distractor pair were presented equally often in unrelated and primed trials across infants. This design counterbalanced

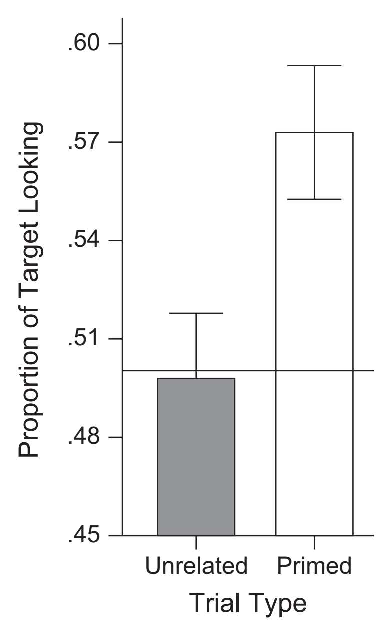

Fig. 2. Mean proportion of time spent looking at the target as a function of trial type. The horizontal line indicates chance performance. Error bars represent standard errors of the mean.

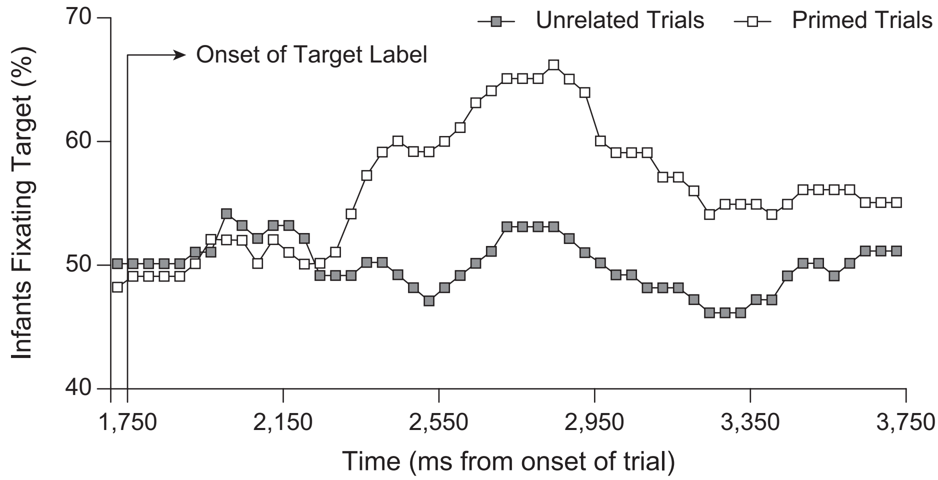

Fig. 3. Mean percentage of infants who fixated the target over the time course of a trial. Results are shown separately for unrelated and primed trials. The target and distractor images were presented 1,700 ms and the auditory stimulus 1,750 ms after the onset of the trial.

any influence that the images presented might have had on the infants, while ensuring modulation of the relationship between the target and prime labels. Furthermore, as the prime, target and distractor labels were semantically and associatively unrelated, the only known relationship between the target and prime images (in primed trials) was a shared onset in the unnamed prime label and the target label.

Infants looked at the target more than 50% of the time (above chance) in primed trials (M = 58%), $t(26) = 3.62$, $p = .001$, but not in unrelated trials (M = 49%), $t(26) = -0.13$, $p > .5$. Note that this effect was not the result of infants not knowing the names of the target images in unrelated trials, as a similar pattern of results was obtained when the analysis included only trials for which infants were reported to know the names of the prime and target images (according to individual Communicative Development Inventory reports; Hamilton, Plunkett, & Schafer, 2000). Even when we excluded trials containing prime or target labels that infants were reported not to know (35% of the original trials), we found that infants still looked longer at the target in primed trials than in unrelated trials, $t(24) = -2.17$, $p = .03$. In addition, infants looked at the target more than expected by chance (50%) in primed trials (M = 58%), $t(24) = 3.87$, $p = .001$, but not in unrelated trials (M = 52%), $t(24) = 1.2$, $p > .2$.

These results indicate a clear priming effect. However, they are ambiguous as to the direction of the effect. It is possible that the related prime facilitated looking at a target, that the unrelated prime interfered with looking at a target, or that both effects occurred. Further research would be required to determine which of these possibilities is correct, but other studies using the intermodal preferential-looking task suggest that an interference interpretation is most likely. When a target object is named in the absence of a prime, infants typically respond by looking more at the target object (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Reznick, 1990). Hence, the lack of systematic looking at the target in the unrelated condition of our study strongly suggests an interference interpretation of our results for this condition. Semantic priming experiments with infants yielded very similar results (Arias-Trejo & Plunkett, 2009): Infants did not show target recognition when the prime and target were semantically and phonologically unrelated, but did show robust target recognition when the prime and target were semantically related. In another study (Arias-Trejo & Plunkett, 2010), perceptual and category competition effects from distractor pictures interfered with 18-month-old infants' target preferences in visual-world tasks.

The findings of our study clearly indicate that the unnamed prime picture influenced infants' processing of the target word (and target image). As in Meyer et al. (2007), this finding can only be explained by assuming that infants internally generate a label for the unnamed prime picture and this internally generated label influenced infants' responses in our study. We also calculated the amount of time the infants took to switch from the target to the distractor or from the distractor to the target after onset of the target picture's label. When infants fixated the target image first, there was a significant difference across conditions (primed vs. unrelated) in the time taken to switch away from the target image and fixate on the distractor image, $t(100) = -2.144$, $p = .034$. Infants switched faster from the target to the distractor image in unrelated trials (M = 853 ms, SEM = 43) than in primed trials (M = 992 ms, SEM = 47). Exposure to the prime therefore significantly influenced the pattern of the infants' eye movements and the time infants spent fixating the target. In contrast, there was no difference in the latency of infants' switches from the distractor to the target image between primed (M = 806, SEM = 54) and unrelated trials (M = 847, SEM = 44), $t(108) = 0.59$, $p = .5$.

Our findings can be explained via an analysis of the processes underlying infant eye movements in the priming task. If infants first fixated the distractor image, then they had not yet identified the target image and were still unaware of the phonological relationship between the target label and the prime label. Therefore, a switch in gaze to the target image (from the distractor image) would have been uninfluenced by the priming condition. Furthermore, there was no attested relationship between the distractor and the prime label to influence switches away from the distractor image. If infants first fixated the target image, the phonological overlap between the implicit and heard labels in primed trials maintained infants' attention on the target image. In contrast, on unrelated trials, the heard label violated expectations generated by the implicit label. This account is supported by our finding that the latencies in shifting away from the target and distractor image were almost identical to each other in the unrelated condition (853 ms vs. 847 ms).

Conclusion

This study used a variant of the task employed by Meyer et al. (2007) to investigate whether priming with an unnamed image influences infants' eye movements to images whose labels are phonologically related to the unnamed prime image's label. Our results demonstrate that, like the adults tested by Meyer et al., 18-month-olds can implicitly generate the names of visually fixated images. This conclusion is based on the contrasting patterns of eye movements observed in the primed and unrelated conditions. Implicit naming is the most likely and straightforward explanation for our results because through our experimental design, we systematically controlled for other potential contributing factors, such as visual similarity or semantic and associative relationships.

How do we reconcile this finding with other studies suggesting that implicit naming of objects does not guide eye movements in visual search tasks? We suggest that these diverse patterns of results need not be incompatible with each other. For example, our experiment did not introduce modulations of the visual similarity of the prime and target images (Dahan & Tanenhaus, 2005), the frequency of the prime and target labels (Dahan, Magnuson, Tanenhaus, & Hogan, 2001), or the processing of novel labels (Swingley & Fernald, 2002). Such manipulations may have overridden any effects of implicit naming in these other studies. As other researchers have suggested before us (Huettig & McQueen, 2007), eye movements in a visual search task are driven by a wide range of factors participating in a tug-of-war, the resolution of which depends on the demands imposed by the specific task. By controlling for the influence of other factors, the experiment described here provided evidence that even the cognitive systems of 18-month-olds participate in this tug-of-war and that implicit naming is one of the factors involved.

This ability of infants to hear the names of objects in their minds' ear may have important implications for their developing semantic systems. The spontaneous co-occurrence of objects and events in the world, even in the absence of an interlocutor, offers the infant implicit linguistic clues for coding thematic and taxonomic relations between words in their language. This implicit naming function may prove one of the core building blocks for infants when constructing a mental lexicon and organizing their semantic system.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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