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Lexical competition in young children's word learning

Daniel Swingley* and **Richard N. Aslin**†

* *Department of Psychology, University of Pennsylvania, 3401 Walnut St. 302C, Philadelphia, PA 19104*

† *Department of Brain and Cognitive Sciences, Meliora Hall, University of Rochester, Rochester, NY 14627*

Abstract

In two experiments, 1.5 year olds were taught novel words whose sound patterns were phonologically similar to familiar words (novel neighbors) or were not (novel nonneighbors). Learning was tested using a picture fixation task. In both experiments, children learned the novel nonneighbors but not the novel neighbors. In addition, exposure to the novel neighbors impaired recognition performance on familiar neighbors. Finally, children did not spontaneously use phonological differences to infer that a novel word referred to a novel object. Thus, lexical competition—inhibitory interaction among words in speech comprehension—can prevent children from using their full phonological sensitivity in judging words as novel. These results suggest that word learning in young children, as in adults, relies not only on the discrimination and identification of phonetic categories, but also on evaluating the likelihood that an utterance conveys a new word.

Keywords

word learning; language acquisition; phonology; categorization; child development

To understand speech, listeners must identify the sequence of words composing each utterance. Because even words repeated by the same talker never sound exactly the same twice, this identification process requires listeners to discount perceptible but irrelevant phonetic characteristics such as speaking rate and overall pitch, while attending to phonetic characteristics that distinguish words. Furthermore, the dynamic nature of the lexicon adds a complex additional component to speech comprehension. Because new words can enter the vocabulary at any time, listeners must be alert to the possibility that a phonetic variant of a familiar word is, in fact, a novel word to be learned. Appropriately balancing interpretation of phonetic variation is particularly crucial early in language development, when many words are being learned and while phonetic perception is still undergoing language-specific tuning. In the present research we examined this process, focusing on word learning in one and 1/2-year-olds.

Interpretation at both the lexical and phonetic levels is rapid and automatic in young children — words are said to be "activated" as the signal unfolds, according to the match between the signal and representations in the lexicon (e.g. Marslen-Wilson, 1987; Swingley, Pinto, & Fernald, 1999), while the acoustic signal is "assimilated" to the set of phonetic categories in the phonological inventory (e.g. Best, 1994). The need for these sources of information to be balanced carefully is seen clearly when children are confronted with novel words that sound similar to words they already know. Phonological analysis may suggest the presence of a novel

Correspondence should be directed to the first author at 3401 Walnut Street 302C, Department of Psychology, University of Pennsylvania, Philadelphia PA 19104; phone, 215-898-0334; email, swingley@psych.upenn.edu.

word, but the resemblance of the novel sequence to a familiar lexical item may support identification of the word as familiar.

One possible resolution of this tradeoff is that the rapid pace of vocabulary expansion in young children may lead them to be especially open to considering poorly matching forms as new words, favoring expansion of the lexicon over ignoring lexical variability. An alternative possibility is that children place relatively little confidence in their phonological analyses of speech, favoring interpretation of "near misses" of familiar words as instances of those words. At present, little is known about how children weigh these different sources of information, though some evidence suggests an increasing reliance on phonological analyses from 2.5 years to 4 years and adulthood (Jarvis, Merriman, Barnett, Hanba, & van Haitsma, 2004). Assessment of this weighting process may contribute to a better understanding of the interaction between linguistic levels in lexical acquisition.

A common assumption in models of language learning in infancy is a "bottom-up" developmental course in which phonetic categories are learned first, the early words are learned second, and syntactic categories and operations are learned last. Indeed, infants are well on their way to forming their native language's phonetic categories by 6–12 months, and their first words are spoken at the end of this age period (e.g., Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Polka & Werker, 1994; Werker & Tees, 1984). Syntactic development depends upon knowing words, and generally follows infants' acquisition of a substantial vocabulary. According to this simple "phonology first" progression, young children's word learning should not be encumbered by phonological insensitivities.

However, it is now clear that word learning begins earlier than once thought, and also that phonological learning is a protracted process extending into middle childhood. Some evidence for precocious word learning concerns infants under the age of 6 months—children who on current evidence have not yet learned language-specific phonetic categories. For example, 4.5-month-olds prefer to listen to their own name rather than a foil (Mandel, Jusczyk, & Pisoni, 1995). Six-month-olds can use the presence of their own name or the word *Mommy* (though not the variant *Tommy*) in an utterance to help identify the boundaries of adjacent words (Bortfeld, Rathbun, Morgan, & Golinkoff, 2005), and they look appropriately at a videotape of their mother or father upon hearing *Mommy* or *Daddy* (Tincoff & Jusczyk, 1999). Thus, early in development at least some words are learned as categories that can guide interpretation of speech, although the specificity of these early lexical representations remains uncertain.

In this same 6–12 month age period, infants begin to refine their perception of speech to focus on phonological distinctions made in the native language. These changes in early perception are manifested empirically in infants' developing failure to distinguish similar speech sounds that are not used contrastively in the native language. For example, both Catalan and Spanish 4-month-olds distinguish the vowels [e] and [/ε/], which are different vowels in Catalan but are treated as a single category in Spanish. By 8 months, Spanish learners no longer discriminate the vowels, though Catalan learners still do (Bosch & Sebastián-Gallés, 2003). Such developmental changes have been shown in vowel perception as early as 6 months (e.g. Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Polka & Werker, 1994) and in consonants at around 11 months (e.g. Werker & Tees, 1984; see also Cheour et al., 1998; Polka & Bohn, 1996). These early changes in speech categorization are followed by increasing refinement of phonetic categorization well into middle childhood (e.g. Hazan & Barrett, 2000; Nittrouer, 1992).

The fact that lexical and phonological categories develop contemporaneously suggests two possible directions of influence from one linguistic level to the other. First, as lexical categories become better entrenched, children might use them to help determine when two similar sounds should be counted as phonologically distinct. For example, many dialects of American English contrast the similar vowels /ɔ/, as in *caught*, and /ɑ/, as in *cot*. Both vowels are frequent in words that infants have probably encoded as familiar forms: /ɔ/ in *all*, *off*, *ball*, and *water*, and /ɑ/ in *on*, *mommy*, *not* and *got*, among others. In principle, variation in the lexical contexts of these vowels might help infants recognize that the acoustic differences between them signal separate phonological categories, just as correlated cues to category identity aid in other category learning situations (e.g. Garner, 1974; Melara & Marks, 1990).

Interaction between phonological and lexical categories could also affect interpretation in the reverse direction: as phonological categories become increasingly robust, children may use them to distinguish between words, or to determine when a variant of a familiar word is or is not sufficiently different to be counted as a distinct word. Indeed, this use of phonological difference as a sufficient and, except in the case of homophones, necessary marker of lexical distinctions may be viewed as the main function of phonological categorization (e.g. Trubetskoy, 1939/1969). This interpretation process is the subject of the present experiments.

Children's adoption of a phonological criterion for differentiating words depends upon their having stored reasonably complete phonological representations of familiar words. If, for example, children's knowledge of the sounds of a word like *ball* were limited to only a vague sense that some stop consonant should be followed by a vowel and a sonorant consonant, it would be impossible for children to tell which new sound-forms differ by at least one phonological unit and which differ by less than that. Whether children do encode phonologically detailed representations of words has been a matter of debate for many years (e.g. Eilers & Oller, 1976; Shvachkin, 1948/1973; Walley, 1987; Waterson, 1971). The conclusion we draw from this debate is that for words children know well, like *dog* and *Mommy* and *baby*, children's phonological representations are complete rather than vague. For words with which children have had much less experience, there is evidence for underspecification of their forms.[1] Studies supporting these conclusions are reviewed below.

Some experiments examining infants' phonological knowledge of familiar words took advantage of 7– to 11-month-olds' preference for listening to familiar words over unfamiliar words, testing whether this preference would be maintained when the familiar words' pronunciation was altered. Maintenance of the familiar-word preference (indifference to mispronunciation) is compatible with underspecification of phonological form, while disappearance of the preference when words are mispronounced suggests that infants retain specific phonological details in words. In a word segmentation task, Jusczyk and Aslin (1995) showed that 7.5-month-olds correctly recognized target words (*cup*, *dog*, *bike*, *feet*) after hearing those words embedded in multiword fluent speech. However, infants did not falsely recognize mispronounced versions of those target words (*tup*, *bog*, *gike*, *zeet*). Although early results showed little influence of mispronunciations on French infants' lexical preferences (Hallé & de Boysson-Bardies, 1996), subsequent experiments with English infants, coupled with reanalysis of the French data, suggested that in fact both English and French infants are affected by mispronunciations of words, at least in stressed syllables (Vihman, Nakai, DePaolis, & Hallé, 2004). In a similar series of experiments, Swingley (2005a) found that Dutch 11-month-olds' lexical preferences were disrupted by mispronunciation of either onset or offset consonants of monosyllabic words. Thus, infants' phonological knowledge of consonants in at least some words appears to be fairly specific in the sense that deviations from citation forms render words poorer matches to infants' stored representations.

[1]By *underspecification*, we refer only to the notion that children's knowledge might be incomplete or vague. Our use of the term is not intended to imply the notion in theoretical phonology that a sound might be phonetically accurate but phonologically inactive (e.g. unable to trigger feature spreading).

Other studies have used picture-fixation or “eyetracking” tasks, together with mispronunciation manipulations, to test slightly older children. When children are presented with pairs of pictures (e.g., an apple and a ball) and a spoken utterance (e.g., *Where’s the ball?*) they tend to fixate the picture that is named in the utterance (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987). In studies of children ranging from 14 to 23 months, Swingley and Aslin (2000, 2002) found that this target fixation response diminished when the target word was mispronounced. For example, upon hearing *Where’s the gall?*, children looked at the ball less than when hearing *Where’s the ball?*. In these studies, children did tend to look at the target picture even when its name was mispronounced, though not always significantly above chance. Similar effects have been demonstrated in other studies (Bailey & Plunkett, 2002; Swingley, 2003; White, Morgan, & Weir, 2004) and in related experiments using audiovisual habituation methods with 14-month-olds (Fennell & Werker, 2003). The latter studies again showed that for familiar words like *ball*, *dog*, and *apple*, even young oneyear- olds appear to encode words with a high level of phonological specificity.

The fact that many words in children’s early vocabularies are encoded with full phonological specification indicates that in principle children could use a phonological criterion for distinguishing novel words from familiar ones. However, other studies have revealed important limitations in young children’s interpretation of speech during word learning (Cummings & Fernald, 2003; Stager & Werker, 1997a; Swingley, under review; Werker, Fennell, Corcoran, & Stager, 2002). For example, Werker and her collaborators have shown that under some conditions 14-month-olds apparently fail to learn two discriminable but similar-sounding novel words, while they succeed in learning two different-sounding words (e.g. Werker & Curtin, 2005). By 17 months, children succeed in the same procedure (Werker et al., 2002). In a related study, Mills et al. (2004) compared ERP responses to correct pronunciations of familiar words, mispronunciations of those words, and nonwords. At 14 months, a negative ERP component between 200 and 400 ms was found to be larger for correct pronunciations and mispronunciations than for nonwords; at 20 months, this component was larger for correct pronunciations than for mispronunciations or nonwords. These results suggest that between 14 and 20 months, children’s categorization of mispronounced words changes in some way. Though the behavioral consequences of this change are not clear, one interpretation is that the 20-month-olds treated the mispronunciations as nonwords because they used a more finely tuned phonological difference criterion to categorize the mispronunciations as nonwords.

The fact that speech processing is a limiting factor in word learning is supported by other studies revealing that individual differences in a range of speech processing measures are correlated with vocabulary development. For example, ERP measures have linked very young infants’ responses to phonetic stimuli and linguistic performance several years later (Guttorm et al., 2005; Molfese, 2000). Tsao, Liu, and Kuhl (2004) documented a significant association between 6-month-olds’ performance in discriminating a nonnative vowel contrast, and vocabulary size at 13, 16, and 24 months. By the end of the second year, children’s latency to respond to a familiar word in a picture fixation task is strongly correlated with both lexical and grammatical measures (Fernald, Perfors, & Marchman, 2005). Even in children as young as 3 years, word and nonword repetition abilities (seen as an index of phonological working memory) are correlated with receptive vocabulary size (Gathercole & Adams, 1993).

Thus, the analytical abilities revealed by infants in learning the phonetic categories of their native language do not guarantee that young children will assume that perceptible phonological variation signals a lexical distinction. In fact, experimental evidence shows that under challenging conditions older children often fail to interpret phonological differences this way. In a series of studies, Merriman and colleagues have examined children’s responses when asked to choose between a familiar object and a novel object upon hearing a novel word (Jarvis, Merriman, Barnett, Hanba, & Van Haitsma, 2004; Merriman & Marazita, 1995; Merriman &

Schuster, 1991). Under these conditions, when the novel word does not resemble the name of the familiar object, children generally interpret the novel word as a name for the unfamiliar object (e.g. Markman & Wachtel, 1988). But this response was not shown consistently when the novel word was phonologically similar to the familiar object. For example, children might see a flower and a palette, and hear "Point to the glower." Although children's responses varied with a number of factors (such as the trial structure and the nature of the phonological resemblance), in general preschool children were less likely to infer that the novel word corresponded to the novel object when that word was phonologically similar to the pictured familiar object than when it was not. Note, though, that in these studies children were placed in a particularly difficult position: to interpret a word like *glower* as a name for the unfamiliar object rather than the flower, they must not only detect the difference between *flower* and *glower*, but must also treat as coincidental the similarity between the novel word and the name of the familiar object. Hence, this task may be too stringent to serve as a general test of children's ability to interpret phonological variation under normal word-learning circumstances.

The present experiments examined the interaction of the lexical and phonological levels of linguistic analysis in one and 1/2-year-olds' word learning by presenting a novel object and labeling it with a name that was or was not similar to a word children already knew (for example, *tog*, a variant of *dog*, or *shang*, which is not similar to a familiar word). As described above, novel words like *tog* pose a problem of interpretation: the lexical level may supply the interpretation that among the words of the lexicon, *dog* is the best match, leading to activation of that word and its meaning. On the other hand, phonological analysis should reveal that in fact *tog* is a distinct word, not a match to *dog*. In principle, this mismatch should be sufficient to support rejection of *dog* as the intended referent, and consideration of *tog* as a potential addition to the lexicon.

The foregoing predictions contrast with those that have emerged from work with adults. In some tasks, such as speech shadowing (Marslen-Wilson & Welsh, 1978) and mispronunciation detection (e.g. Cole, Jakimik, & Cooper, 1978), phonologically novel word-forms are often interpreted as similar words even by adults. Such behavior need not be considered maladaptive; indeed, talkers may misspeak and listeners may misperceive, so loose criteria for matching heard words to lexical representations can be helpful, particularly when (as in these shadowing and detection studies) mispronunciations are slipped into meaningful sentences. However, since adults know most of the words they hear, it makes sense for them to be biased in favor of resolving utterances as sequences of familiar words. Children, by contrast, probably know fewer of the words they encounter, and know only a fraction of their ultimate vocabulary. Our initial expectation, then, was that young children would seize upon perceptible phonological distinctions (like the [t] and [d] in *tog* and *dog*), readily using the output of phonological analysis to learn new words in spite of phonological similarities. This prediction was tested in two experiments.

Experiment 1

In Experiment 1, children about 1.5 years old were taught two novel words for novel objects. One novel word was a phonological neighbor of a familiar word (where *neighbor* refers to a word differing from another word by addition, deletion, or substitution of a single segment; Luce & Pisoni, 1998). (We will refer to these taught words as "novel neighbors", and will call the familiar words from which they were derived "familiar source words".) The second novel word was not a neighbor of any words children were likely to know. Children's learning was tested using a visual fixation procedure (Swingley, Pinto, & Fernald, 1998). On some trials, children viewed a large screen displaying one of the novel objects paired with a familiar object; on other trials, children viewed both novel objects on the screen. A prerecorded utterance directed children's attention to one of the displayed objects by name. Children's eye movements to the named pictures were used as the measure of word recognition.

The novel neighbors of familiar words that children were taught had been used as stimuli in previous studies of children's word recognition (Swingley & Aslin, 2000, 2002). In those studies, children ranging from 14 to 23 months of age were shown pictures of two familiar objects (e.g. a dog and a baby) and heard sentences that named one of the pictures using a correct pronunciation (*Where's the dog?*) or a mispronunciation (*Where's the tog?*). Children consistently fixated the target picture less upon hearing the mispronunciations than upon hearing the correct pronunciations. This was true over the entire age range tested, for all 6 words tested, and the effect was independent of children's age or vocabulary size. Children above 17 months of age were more likely to look at the referent of the mispronounced word than at the alternative mismatching picture, indicating that they were able to recognize the mispronounced word, though apparently only with difficulty. The novel neighbors that were taught in Experiment 1 were selected from this set of mispronunced words that had yielded mispronunciation effects in children from the same population. Thus, the novel neighbors probed the relevant conflict: they were discriminably different from their familiar source words, yet children in previous studies who were given only two familiar objects to choose from were nevertheless above chance in interpreting the mispronunciation as an instance of its familiar source word.

Methods

Overview—Children of about 19 months were taught a novel neighbor and a novel nonneighbor as words for novel objects. Half of the children were taught *tog* (neighboring the familiar source word *dog*) and *meb* (a nonneighbor); the other half were taught *gall* (neighboring the familiar source word *ball*) and *shang*. Both *dog* and *ball* are words known by children this age. According to the parental report measures of Fenson, Dale, Reznick, Bates, Thal, & Pethick (1994), almost 90% of 16-month-old infants understand *dog*, and almost 95% understand *ball*.[2] Similarly, over 82% of 19-month-olds were reported to say *dog*, and 95% said *ball*. The word *tog* differs phonologically from *dog* in the voicing value of the initial consonant, while *gall* differs from *ball* in the place of articulation of the initial consonant.

Word teaching was done in two phases: first in a game using real objects, and then on a large computer monitor. Test trials followed the on-screen teaching. On each test trial, two (or for some filler trials, three) pictures were displayed, and a prerecorded speech stimulus named one of the pictures in a sentence.

The test phase consisted of 25 trials in two blocks (see Table 1). In the first block, children were tested on six *both-familiar* filler trials and six *both-novel* trials. On *both-familiar* trials, children were shown familiar objects (e.g. a ball and a car) and heard a sentence naming one of them. On *both-novel* trials, children were shown the two novel objects side by side, and one was named in a sentence. The second block of trials comprised five additional *both-familiar* trials and eight *one-novel* trials in which the display contained one of the novel objects and also a familiar object. Here, when the displayed novel object had been labeled with a novel neighbor (e.g. *tog*), the alternative picture corresponded to the novel neighbor's familiar source word (a picture of a dog). Thus, half of the *one-novel* trials asked children to distinguish a novel word (the novel neighbor) and a similar-sounding familiar word (the familiar source word). The other half of the *one-novel* trials served as a baseline condition in which phonological similarity was minimal, but one picture was still a novel object and one was familiar (e.g. *shang* heard labeling a picture of a "shang" and a baby).

[2]In Fenson et al.'s norming study, comprehension was not assessed above 16 months.

If children's sensitivity to phonetic information outweighs their tendency to interpret novel word-forms as instances of familiar words, then good performance for both of the newly taught words would be predicted on *both-novel* trials. Furthermore, children should fixate the named object under conditions of close phonological competition (e.g. seeing a dog and a *tog*, and being asked for either one) just as much as when phonological competition is minimal (e.g. seeing a baby and a *shang*, and being asked for either). Alternatively, children's interpretation might be driven more strongly by the activation of familiar words. If so, learning novel neighbors should be difficult, which would be reflected in inferior performance on all trials that test the novel neighbors.

Participants—The 70 children in the final sample ranged in age from 17,23 (months, days) to 20,17, with a mean of 18,28 (SD = 17 days). Thirty-seven were girls. Boys and girls were similar in age (mean male age, 579 days; mean female age, 572 days). All children were full-term well-baby births, with American English as the primary language of the caregivers. An additional 67 children participated but were not included in the final data set. Of these, 51 began the study but did not complete at least 18 of the test trials (a relatively high attrition rate which may be attributed to the long procedure). To complete a trial, children were required to fixate either picture within the test window (defined below). Other children were excluded because of experimenter error or equipment failure (13) or because a Communicative Development Inventory (Fenson, et al., 1994) was not obtained (3).

Novel object stimuli—One novel object was a bright yellow plastic bottle-opener with several blue shower-curtain rings attached to its open end (see Figure 1). The other novel object was a rectangle constructed of clear and opaque plastic tubing, with brightly colored plastic beads inside suspended in water. These objects were introduced and named in a teaching game as described below.

Visual stimuli—The visual stimuli were digitized photographs of objects on a gray background, presented on an 80 cm Sony PVM-3230 color video monitor. The set of pictures shown on test trials included the two novel objects, a ball, a car, a dog, and other familiar objects. Pictures were of similar sizes, averaging about 13 cm in diameter, and were separated by about 18 cm. Children were seated on their parent's lap about 80 cm from the screen, with the pictures just above eye level. Three of the eleven filler trials (the "both-familiar" trials) displayed three pictures, with two in the lower corners of the screen and the third centered at the top; on all other trials, pictures were centered vertically and placed near the horizontal edges of the display. The three-picture trials were intended to reduce attrition by adding variety; results from these trials are not reported here.

Auditory stimuli—The speech stimuli were digitally recorded by a female native speaker of American English in a sound attenuated room, sampling at 22,050 Hz. Her speaking rate was slow and in a moderately "infant-directed" register. Stimuli used in the on-screen teaching phase included the sentences *Look, there's a [novel-word]!*, *Look at the [novel-word]*, and three intonational variants of the novel word in isolation. Test trials included two sentences separated by 750 ms of silence. The first sentence was *Where's the [target]?*. The second sentence varied. On filler trials, the second sentence was *Do you like it?*. On *both-novel* trials, the second sentence was *See the [target]?*; and on *one-novel* trials, the second sentence was *Do you see it?*. Second sentences were included to help motivate the children by varying the presentation. Data analyses were computed over a window that did not include the final nouns or pronouns of the second sentences, as described below. Durations of the target words on the test trials were as follows (durations include the closure of initial stop consonants). Novel words: *gall*, 886 ms; *meb*, 751 ms; *tog*, 910 ms; *shang*, 871 ms. Familiar words: *baby*, 1058 ms; *ball*, 765 ms; *car*, 731 ms; *dog*, 945 ms; *duck*, 599 ms; *fish*, 708 ms; and *shoe*, 692 ms.

Apparatus and procedure—Before coming to the laboratory, parents completed a consent form and the MacArthur-Bates Communicative Development Inventory (Words and Sentences CDI; Fenson et al., 1994). When parent and child arrived at the lab, they were brought into the testing room by the experimenter. The parent sat in a chair while the first experimenter sat on the floor with the child, introducing a game with a toy bucket. The bucket was prepared with a black felt cover containing an aperture just wide enough to permit retrieval of small objects. First, the experimenter removed a toy car from the bucket, labelling it (as a car) with enthusiasm, and playing with it together with the child. After about half a minute of this play, the car was retrieved from the child and placed back in the bucket. Then the experimenter removed a second toy, either the modified bottle-opener or the rectangle of tubing, showed it to the child, and named it by going through the following script two times: "Look! That's a [target]. [Target]. This is a [target]. Do you see the [target]? Look at the [target]." The experimenter paused as necessary when doing this routine to ensure that the child was attending to the object every time the novel word was uttered. Then the toy was replaced in the bucket and the procedure was repeated for the other novel object. Whether the phonological neighbor was used as the label for the bottle-opener or the PVC rectangle was counterbalanced across infants in both the *tog, meb* and *gall, shang* groups. In half of the experimental orders, the neighbor was taught first and the nonneighbor second; in the other half, the reverse order was used.

Once this teaching sequence was complete, the experimenter ushered the parent and child to a three-sided cloth-walled booth about 2 m tall and 1.2 m wide just adjacent to where the teaching had been done. The computer display formed the back section of the booth. Parents sat in a desk chair facing the monitor while the child sat on the parent's lap. Parents had been instructed to try to keep their child on their lap and facing the monitor throughout the procedure. Parents were also asked to refrain from speaking, and to close their eyes and bend their head downward throughout the trials. (Parents not closing their eyes when the first trial began were instructed to do so; thus, parents were blind to target side.) Speech stimuli were delivered through a concealed central speaker beneath the monitor. The child's eye movements were monitored using a videocamera placed about 10 cm below the monitor.

The test trials were preceded by additional teaching on-screen. This teaching was integrated with a 9-point calibration sequence for use with a semi-automated eye tracking system (sparse data from this system precluded their use in the present study). In this sequence, children saw an object appear in the center of the screen, and then move around on a curving connected path until it came to rest in one of nine locations. On five of the nine animated sequences, the object was a duck, goldfish, or beagle accompanied by brief sound effects. In the other four sequences, one of the novel objects appeared on the screen, and was labeled in synchrony with changes in its path as it moved. The labeling sequence was: "Look, there's a [target]! [Target.] [Target.] [Target.] Look at the [target]." The identity of the target over the four labeling sequences alternated. For those children who had been taught the phonological neighbor first in the play session, the nonneighbor came first in the on-screen teaching; the reverse was true for children taught the nonneighbor first in the play session.

Thus, children's total training on each of the novel words included 20 repetitions (10 in the game with real objects, 10 on screen), uttered in a child-friendly voice in sentence-final position and often as an isolated word. These features were intended to maximize the likelihood that children would attend to and correctly encode the novel words (Swingley, under review).

The test phase consisted of 25 trials. Each trial began with the simultaneous presentation of two pictures, positioned at the left and right of the screen and centered vertically. Three seconds later, the auditory stimulus began. The trial ended about 3.5 s after the target word's onset.

Trials were separated by a one-second pause in which the display was black. The entire on-screen procedure, including the ostensive labeling, lasted about 5 min.

In the test trials, target side (left or right) was never repeated more than twice consecutively, and all pictures appeared on the left and right equally often. Each test order had a "partner" test order constructed by replacing the novel neighbor picture and its associated soundfiles with those of the novel nonneighbor, and vice versa, thereby counterbalancing the two conditions of interest with respect to extraneous factors. Each order was used to test 8–10 children, with an approximately equal number of boys and girls in each order.

Coding—Videotapes of the children's faces as they looked at the screen were stamped with a digital timecode labeling each video frame (33 msec intervals). Coders examined the videotapes frame by frame, noting the time of each change in children's gaze direction. Coding was done by several highly trained coders whose reliability (mean percent agreement, 95.4; mean Cohen's kappa, 93.2) was established by re-coding blocks of 6 consecutive trials of 16 children tested in a similar experiment run largely concurrently with the present one, using the same apparatus and testing conditions (Swingley & Aslin, 2000).

Results

As in previous studies (e.g. Swingley & Aslin, 2000, 2002) children's word recognition was evaluated by analyzing eye movements during a temporal window beginning 367 ms after the onset of the target word and extending to 2000 ms after the onset of the target word. Previous research has shown that this time period is the window in which young children's eye movements are most strongly contingent on the target words. The 367 ms onset is also motivated by research on infant eye movements showing that even in simpler tasks, *minimum* eye-movement response latency is on the order of 233 ms, with mean latencies often much larger (e.g. Canfield & Haith, 1991; Hood & Atkinson, 1993).

Children's proportion of fixation to the target picture was computed for each trial by counting the number of frames on which children fixated the target picture, and dividing this sum by the total number of frames on which children fixated either the target or the distracter. In most of our previous work, in which children were tested on words parents said they knew, this proportion was compared to 50%. The chance baseline of 50% reflected the assumption that (on average) children would fixate each picture equally until they perceived and understood the spoken word. Because pictures were yoked in counterbalanced pairs, overall above-50% performance could be taken as evidence that children recognized at least some words.

Here, because one of our goals was to establish whether children learned and recognized *particular* words, and not just words in general, we used a baseline that took into account children's prior preferences for fixating each picture. Following Fernald & McRoberts (in Fernald, McRoberts, & Swingley, 2001), a *salience score* was computed for each image in each picture pair. This score was computed by averaging the proportion of fixation to each picture from the onset of the trial to the onset of the spoken word for all trials in which that picture pair appeared. (The analysis concerns images within pairs, rather than just images regardless of their partners, because salience is relative: a picture that is highly salient when paired with something dull may itself be drab when paired with a very attractive picture.) For example, the pair (car, ball) appeared on four trials. Each child's salience score for *car* was computed by averaging each trial's pre-target-word *car* fixation proportion over the four (car, ball) trials. Our chief measure of performance on each trial with a given word was a difference score computed by subtracting this salience score from the test-window fixation proportion. Thus, a score of zero indicated no change from the pre-target fixation baseline to the target fixation elicited by the speech stimulus. Similar measures have been used in other studies (e.g. Oviatt, 1980; Reznick & Goldfield, 1992).[3]

Children's performance on *both-familiar* trials (e.g. baby, dog) was examined for comparison with other studies and to confirm that children were engaged in the task. Salience-corrected fixation proportions averaged 17.7% (SD = 9.6), well above chance ($t(69) = 15.5$, $p < .0001$). Thus, when children heard a familiar word naming one of two familiar pictures, they reliably increased their fixation of the named picture above baseline.

The first substantive questions to be addressed concerned the *both-novel* trials, on which children viewed both of the novel objects and were queried about either the novel neighbor or the novel nonneighbor. When children heard the novel neighbor, salience-corrected target fixations averaged just 0.17% (SD = 0.20); when children heard the novel nonneighbor, target fixations averaged 8.64% (SD = 0.21), as depicted in Figure 2. Only fixations to the referent of the novel nonneighbor were significantly greater than zero ($t\ (69) = 3.46$, p(two-tailed)$< .001$).[4] This difference between novel neighbor and novel nonneighbor fixation was significant (paired $t\ (69) = 2.07$, $p < .05$). Thus, children learned the novel nonneighbor, but failed to show evidence of learning the novel neighbor. Analyses of variance found no effects of sex, experimental order, or word-pair taught (viz. *meb, tog* vs. *shang, gall*), and no interactions with the significant condition effect (neighbor vs. nonneighbor).

In the second block of the experiment, children were exposed to eight trials on which one picture was a newly learned object and the other was a familiar object (the *one-novel* trials). To determine whether children could differentiate the novel neighbors from their phonologically similar partners (e.g. differentiating *tog* from *dog*), the critical 1-novel trials displayed the referent of the novel neighbor together with the referent of the familiar source word (e.g. the dog with the "tog"), and named the novel neighbor (e.g. *Where's the tog?*).

Children performed above chance on trials testing recognition of novel neighbors (e.g. *tog*, with *dog* as the distracter picture); upon hearing novel neighbors, target fixation averaged 8.6% above baseline ($t\ (64) = 2.5$, $p = .017$).[5] Children also performed above chance upon hearing novel non-neighbors (e.g. *meb*, with *car* as distracter; see middle pair of bars in Fig. 1). Upon hearing novel non-neighbors, children's target fixation averaged 19.5% ($t\ (69) = 6.1$, $p < .0001$). Children's performance on novel nonneighors was significantly better than their performance on novel neighbors ($t\ (64) = 2.11$, $p = .039$).

Three related trial types were also included in this second block of test trials. First, two trials showed these same pictures but presented the familiar word (e.g., "dog"). These trials helped evaluate the possibility that learning a novel neighbor would impair recognition of the familiar source word. Four more trials displayed the non-neighbor's referent and a phonologically unrelated familiar picture, and labeled one or the other (two trials each). The mean target fixation proportion given familiar nonneighbors *car* and *baby* was 13.8% above baseline ($t\ (68) = 4.78$, $p < .0001$), and to the familiar source words *dog* and *ball*, 10.8% above baseline ($t\ (68) = 3.79$, $p < .001$); see rightmost pair of bars in Figure 2). Though performance was somewhat worse in the familiar-source-word condition, these proportions were not themselves significantly different ($t(67) = 1.09$, ns), which could be taken as evidence that exposure to novel neighbors did not impact recognition of the familiar source words. However, a more sensitive test would examine possible influences of being taught a particular novel neighbor

[3]Analyses using raw proportion-to-target scores and a baseline of 50% yielded a similar pattern of results and significance to that found using salience scores.

[4]Probabilities in t-tests were two-tailed in Experiment 1, reflecting relatively weak *a priori* bases for expecting effects in a particular direction for some conditions.

[5]Analyses of *response latency* (Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998) revealed associations between performance and vocabulary size only for the *both-familiar* (filler) trials, for which response latency was negatively correlated with log-transformed vocabulary size ($r = -0.447$; $t(64)= 4.00$, $p < .0005$). Children with larger vocabularies responded to familiar words more quickly than children with smaller vocabularies.

(like *tog*) on the recognition of its partner, the familiar source word (*dog*), given an estimate of baseline performance on that familiar word (*dog*).

The first such analysis examined whether exposure to (e.g.) *tog* reduced children's performance on the *both-familiar* trials in which *dog* was the target. This prediction was motivated by consideration of exemplar theories, in which the representation of a category is a function of the set of token experiences identified as members of that category (e.g. Kruschke, 1992; Nosofsky, 1986). If children hearing *gall* sometimes count it as a token of *ball*, this might alter their representation of *ball* enough to impair its recognition on the *both-familiar* filler trials. This result was not obtained. Children taught *tog* were no worse at recognizing *dog* on *both-familiar* trials than the children taught *gall* (20.3% versus 15.1%, nonsignificantly in the wrong direction); children taught *gall* were not hindered in recognizing *ball* on *both-familiar* trials (22.4% versus 25.9%, ns).

A second analysis considered children's performance in recognizing familiar words in the context of novel objects, i.e. on the *one-novel* trials. Perhaps exposure to a novel neighbor would alter interpretation of the familiar source word enough to impair recognition of the familiar source word on the difficult *one-novel* trials relative to the easier *both-familiar* trials. Thus, here we examined target fixation for *dog* among children taught *tog*, and *ball* among children taught *gall*, subtracting *one-novel* performance from *both-familiar* performance. Indeed, individual children's performance on *one-novel* neighbor trials was worse than their performance on those *both-familiar* trials testing the same words, a significant difference of 10.6 percentage points ($t(68)= 3.64$, $p < .001$). By contrast, children were not significantly worse on one-novel *non*neighbor trials than on *both-familiar* trials testing the same targets (1.4% decrement, ns). Thus, simply placing a novel object on the screen did not make recognition of familiar source words more difficult. But exposure to a novel neighbor appeared to impair recognition of its familiar partner when the two were directly in competition on the screen. This suggests that children's uncertainty about the novel neighbor contaminated the familiar source word to some degree. We return to this issue in our discussion of Experiment 2.

Finally, to examine whether children with larger vocabularies were more successful in learning and recognizing words under these conditions, the number of different words each child was reported to produce, based on the MacArthur-Bates CDI checklist, was evaluated with respect to children's fixation results. Children's estimated vocabulary sizes ranged from 0 to 557 (mean 141, SD 137). Neither raw vocabulary size scores nor vocabulary scores log-transformed to reduce skew were significantly correlated with fixation responses on both-novel trials. Analyses of log-transformed scores and performance on one-novel trials revealed positive, but often small, correlations between these measures: novel neighbor trials, $r = .252$ (p(two-tailed) $= .043$); novel non-neighbor trials, .233 ($p = .052$); both of these conditions collapsed, $r = .315$, ($p = .008$). The analogous correlations for one-novel trials on which the target word was a familiar word were not significant (both $r < 0.1$). Thus, the results provided weak support for associations between vocabulary size and word learning skill.[6]

Discussion

Children given brief but intensive teaching exposure to a pair of novel words performed much better when tested on the novel non-neighbors *meb* and *shang* than when tested on novel words *tog* (neighboring the familiar source word *dog*) and *gall*, neighboring *ball*. On test trials requiring children to select the named referent from a set of two novel objects (i.e. on the *both-*

[6]A few children did not fixate the screen on either trial in these conditions, leading to a corresponding reduction in degrees of freedom for the relevant tests.

novel trials), children succeeded for the novel non-neighbors and failed entirely for the novel neighbors. When the test required children to differentiate the novel item and a familiar one (on the *one-novel trials*), children were above chance for both novel neighbors and novel non-neighbors, but performed significantly better on the non-neighbor trials.

In previous word-recognition research, children the same age distinguished the novel neighbors from their familiar partners (Swingley & Aslin, 2000). It is clear, then, that children can hear the difference between (e.g.) *dog* and *tog* and that this difference has measurable consequences for their recognition of *dog*. However, in the present experiment children still revealed difficulty in learning the novel neighbors, suggesting that children this age do not always employ a strict phonological-difference criterion for differentiating words.

Children apparently recognized the novel neighbors to some degree on *one-novel* trials but not on *both-novel* trials. Why might this happen? One possibility is that children had successfully encoded the novel neighbor's sound form, but interference caused by activation of the familiar source word prevented appropriate interpretation or encoding of the novel neighbor's meaning. On the *both-novel* trials, children may have recalled having heard (e.g.) *tog* in the teaching phase, but could not connect this memory to the particular object referred to. On the *one-novel* trials, children with only a vague recollection of which novel object was the *tog* could succeed simply by rejecting the dog in favor of the presented novel object. This account suggests that children's difficulty lies not with phonological encoding of neighbor words per se, but with establishing a robust link between a sound-form and its referent when the sound-form evokes highly familiar alternatives.

A related possibility is that in fact children did not learn the novel words' forms at all, and only succeeded on the *one-novel* trials by exploiting a process-of-elimination strategy: A dog is not a "tog", therefore *tog* must refer to the other object, which has no known name. Children's ability to infer that an entirely novel word refers to an unfamiliar object rather than to one whose name is already known has been demonstrated in a number of studies (e.g. Golinkoff, Hirsh-Pasek, Bailey, &Wenger, 1992; Halberda, 2003; Markman &Wachtel, 1988; Markman, Wasow, & Hansen, 2003; Merriman & Bowman, 1989; Mervis & Bertrand, 1994).[7] Thus, successful performance on the *one-novel* trials does not provide clear evidence that children learned the novel neighbor during the teaching phase of the experiment, because of the possible operation of a "mutual exclusivity" strategy.

There are reasons to doubt that children succeeded here using the process of elimination alone, however. First, there was no sign of such a strategy in responses on *both-novel* trials: children knew the novel nonneighbor (e.g.) *meb*, but did not appear to use this knowledge to reject *tog* as a label for the *meb* object. On the other hand, perhaps for newly learned words, in which the linkage between sound and meaning is still tenuous, children are not inclined to draw strong conclusions based on mutual exclusivity. Second, as described previously, studies by Merriman and colleagues have shown that phonological similarity to a familiar word can reduce or eliminate "mutual exclusivity" based responding. Thus, though present evidence cannot rule out a "mutual exclusivity" basis for children's performance on the *one-novel* trials, it seems more likely that children's choice of the novel object on these trials reflects children's learning of the novel word, though that learning was obviously incomplete.

Experiment 2 had two purposes. One was to evaluate whether children use a "mutual exclusivity" strategy to interpret novel neighbors with which they have had no prior experience. To this end, some children in Experiment 2 were confronted with a novel object, a familiar object, and a novel word that was a phonological neighbor of the familiar object's name. If 18-

[7]For convenience, we will refer to this behavior as adherence to a *mutual exclusivity* bias, following Markman (e.g. Markman, 1989).

month-olds can use a single-phoneme distinction to determine that a novel word differs from a familiar word, we would expect them to show a “mutual exclusivity” response: choosing a novel object, rather than a familiar object, upon hearing the novel word, even if that word were similar to the name of the familiar object. If 18-month-olds do not use a single-phoneme distinction to determine that (e.g.) *tog* cannot refer to *dog*, children might instead look at a dog rather than a novel object upon hearing *tog* (Halberda, 2003; White et al., 2004).

The second goal of Experiment 2 was to examine whether children’s difficulties in learning novel phonological neighbors arise only when children are learning more than one word in a session, possibly due to attentional resource limitations. Effects of learning one versus two novel words have been found in other studies (Liittschwager & Markman, 1994). Thus, in Experiment 2 each child was taught only one word. Children’s failure to learn a novel neighbor when it was the only word being taught, together with other children’s success with novel nonneighbors taught under identical conditions, would provide compelling evidence that neighbors are harder to learn than nonneighbors even when task demands are minimized.

Experiment 2

Children were taught either a novel phonological neighbor of a familiar source word, or a nonneighbor. For both groups of children, the first half of the testing phase consisted of *both-familiar* (filler) trials, and *both-novel* trials. As in Experiment 1, on the *both-novel* trials two novel objects were displayed, and children heard the word they had been taught. Learning was inferred from children’s fixation to the named picture.

In the second half of the testing phase, all children were shown a novel object and a familiar object on the screen, in a series of *one-novel* trials that were interspersed with *both-familiar* (filler) trials. The children who had just been taught a novel neighbor were tested on that novel neighbor. For these children, the *one-novel* trials helped determine if the novel neighbor was learned well enough to distinguish its referent from that of the familiar source word. Analogous trials in Experiment 1 had revealed above-chance performance in fixating (e.g.) the dog when we said *dog*, and the referent of *tog* when we said *tog*.

The children who had just been taught a novel *nonneighbor* were also shown a novel object and a familiar object, but for these children the auditory stimulus was a familiar source word (the name of the pictured familiar object), or a novel neighbor of that source word—a novel neighbor they had never heard before. The novel object was not the object for which they had been taught a name, but rather had never been labeled. Children hearing the familiar word were expected to fixate its referent, the familiar object. If children used a phonological criterion for deciding that the novel neighbor really was a novel word (and not an instance of the familiar source word), they would be expected to fixate the novel object. Alternatively, if the similarity of the novel neighbor to its familar source word dominated children’s interpretation, they would be expected to fixate the familiar object.

Methods

Participants—The children tested in Experiment 2 were monolingual learners of Dutch living in or near the city of Nijmegen. Dutch is a Germanic language with many phonological properties in common with English. The 28 children in the final sample ranged in age from 18,0 (months, days) to 19,1, with a mean of 18,15 (SD = 10 days). Half were girls. Boys and girls were similar in age (mean male and female age, 562 days). An equal number of boys and girls were taught neighbors and nonneighbors. All children were full-term well-baby births, with Dutch as the primary language of the caregivers. An additional 21 children were tested but not included in the final sample. Of these, 20 did not complete at least 10 non-filler test trials, or did not complete at least 3 of the 6 *both-novel* test trials. One additional child was excluded because of equipment failure.

Visual stimuli—In the teaching phase, all children saw pictures of two novel objects. One was the referent of the taught word, the other a distracter. The role of each object was counterbalanced across children. One object was a plush toy shaped like a manta-ray and spotted like a leopard. The other was a plush toy shaped like a dinosaur (a parasaurolophus, more or less), rendered in a brownish orange color. The objects are depicted in Figure 3.

The teaching included four short narrated animations, as well as ostensive displays. Two of the animations used the to-be-taught word five times each, showing the referent engaged in some activity, and two showed the alternative novel object, but used generic terms and pronouns to refer to it. These alternative-object animations were included to equalize children's familiarity with each novel object, though labeling only one of them. In one of the word-teaching animations, the novel object played on a playground slide; in the other, it took a bath. In the distracter animations, the other novel object chased after a truck or was threatened by an impending rainstorm.

The ostensive displays simply showed the target or distracter object on a gray background. The first time these pictures were shown, they were centered on the screen; in the second ostensive sequence, each object moved on a simple geometric path either rising vertically or describing a single arc starting and finishing in the lower corners of the screen. These movements were intended to help maintain children's interest.

All pictures presented on test trials, including those of the novel objects, were digitized photographs placed on a uniform gray background. On-screen, pictures were about 21 cm wide and separated horizontally by about 38 cm. In an effort to motivate children to continue looking at the screen, five wordless animations about 5 s long were interspersed with test trials in the second half of the experiment. For example, in one animation, a kangaroo hopped across the screen, accompanied by "boing" noises at appropriate intervals. As described below, word-teaching was done on-screen, using additional animations. Other features of the stimulus presentation were as in Experiment 1.

Auditory stimuli—The novel phonological neighbors were [dal], a neighbor of *bal* ("ball"), and [xont], a neighbor of *hond* ("dog"). Thus, the item *dal* tested a place of articulation contrast in the onset consonant. The difference between *hond* and *xond* lies in the initial consonant (the /d/ of *hond* is unvoiced in Dutch), with the velar sound having more salient frication noise. A previous study of 19-month-olds from the present participant population showed that children find *bal* relatively difficult to recognize when mispronounced as *dal* (Swingley, 2003); *xond* was tested for the first time. The nonneighbors were [biʃ] and [b/ε/mp], which will be written hereafter as "biesh" and "bemp." Nonneighbor status was examined by comparing these nonce words with words from a Dutch version of the CDI and from a corpus of speech to a Dutch infant (van de Weijer, 1998). Neither of these nonce words had any neighbors by the substitution, addition, or deletion of a single sound.

All speech stimuli were digitally recorded by a female native speaker of Dutch in a sound-proofed room, sampling at 48,000 Hz. The teaching animations included seven sentences. The "playing on a slide" animation was narrated as follows: *Kijk, daar is de [target] weer. Hij ziet een glijbaan. Zie je dat? De [target] gaat naar de glijbaan. Eerst moet de [target] de trap opklimmen. De [target] staat nu helemaal bovenaan. En roetsj, de [target] glijdt naar beneden.* (In English: "Look, there is the [target] again. He sees a slide. Do you see it? The [target] goes to the slide. First the [target] has to climb up the stairs. The [target] is now all the way on top. And whoop! the [target] slides to the bottom.") The "bath" narrative was similar, placing the target word in a range of sentence positions. The distractor-familiarization narratives were of essentially the same form, but used *hij* (“he”) to refer to the novel object.

The ostensive teaching sequences were *Dit is een [novel-word]. [Novel-word.] Een [novel-word]. [Novel-Word.] Zie je de [novel-word]?* (“This is a [novel-word]. [Novel-word.] A [novel-word]. [Novel-Word.] Do you see the [novel-word]?”) and *Hoe noem je dat? Een [novel-word]! Dat is een [novel-word].* (“What do you call that? A [novel-word]! That is a [novel-word].”). The audio sequences for the analogous distracter-familiarization trials were *Kijk! Wat is dat?* (“Look! What is that?”) and *Kijk eens! Wat is dat? Leuk, hé?* (“Look! What is that? Nice, huh?”). Over the seven ostensive naming exposures, the mean durations of the novel words were: *dal*, 431 ms; *xond*, 590 ms; *biesh*, 516 ms; *bemp*, 477 ms.

Word learning was tested using sentences of the form *Waar is de [target]? Kan je de [target] vinden?* (“Where is the [target]? Can you find the [target]?”) on the both-novel trials, and *Kijk naar de [target]. Zie je de [target]?* (“Look at the [target]. Do you see the [target]?”) on the one-novel trials. The first and second sentences were separated by 750 ms of silence. The durations of the target words in the first sentences were, for the both-novel trials, *dal*, 498 ms; *xond*, 513 ms; *biesh*, 472 ms; *bemp*, 481 ms. Durations of targets on the first sentences of the one-novel trials were: *bal*, 410 ms; *dal*, 452 ms; *xond*, 488 ms; *hond*, 475 ms.

Auditory stimuli on *both-familiar* trials used two carrier frames: *Waar is de [target]?* and *Kan je de [target] vinden?*. Target words on these trials included *appel* (“apple”), *baby* (“baby”), *banaan* (“banana”), *beer* (“bear”), *beker* (“cup”), *eend* (“duck”), *fiets* (“bicycle”), *paard* (“horse”), *poes* (“cat”), and *vogel* (“bird”). Only one sentence per trial was presented on the *both-familiar* trials.

Two additional filler trials appearing near the start of the experiment used different carrier frames: *Kijk naar de [target]. Kan je de [target] vinden?* (“Look at the [target]. Can you find the [target]?”).

Apparatus and procedure—Parents completed a Dutch version of the MacArthur-Bates Communicative Development Inventory (Words and Sentences), originally produced by Maryline Lejaegere for studying Flemish children and modified for the Nijmegen population by Swingley (2003). Parents were asked to indicate their children’s receptive and productive vocabulary.

Children entered the testing room with their parent, who chatted briefly with the experimenter before being seated with the child on her lap facing the video screen. The screen was a 127 cm-diagonal video projection screen (Sony KL-X9200M) that formed the back of a three-sided booth 2 m tall, 1.3 m wide, and 1.2 m deep. The speech stimuli were delivered from the loudspeakers of the video screen, and children were videotaped onto DV cassettes via a low-light camera placed about 15 cm below the monitor. Room lighting was dim. Parents were instructed as in Experiment 1.

The experiment began with a brief animated vignette showing the distracter object chasing a truck. This was followed by ostensive labeling of the taught word, and then some generic “look-at-that” talk about the distracter picture. A word-teaching vignette came next (the target using a playground slide), followed by two introductory trials using the words *auto* (“car”) and *schoen* (“shoe”). Next came the teaching animation showing the target about to take a bath and another distracter-familiarization animation. Finally, the distracter appeared on a gray background and was talked about (“Look! What is that?”), and then the final ostensive teaching segment, featuring the novel object being labeled with the novel word, was presented. All told, children heard the novel label 16 times before they were tested on it.

The composition of the experiment proper is laid out in Table 2. The upper half of the table describes the stimuli presented to a child who was taught that *dal* (a neighbor of *bal*) referred to the dinosaur. The lower half of the table shows stimuli presented to a child taught that *bemp* (a nonneighbor) referred to the manta-ray.

As in Experiment 1, a block of *both-novel* and *both-familiar* (filler) trials preceded a block of *one-novel* trials with additional *both-familiar* trials. Eight stimulus orders were created, with two orders testing each of the four novel words. Of these two orders for each word, in one the novel word referred to the ray, and in the other it referred to the dinosaur. Children taught a novel neighbor (viz. *dal* or *xond*) were tested on that word in both blocks of trials. Children taught the nonneighbor *biesh* were tested on *biesh* in the first block (the *both-novel* trials) and were tested on *xond* in the second block. Children taught *bemp* were tested on *bemp* in the first block and *dal* in the second. When children were taught a novel nonneighbor, they heard the novel neighbor for the first time in the second block, when it was used to refer to the novel object that had been the distracter. For example, children taught that the ray was a *bemp* were presented with *one-novel* trials on which the ball and dinosaur pictures appeared, along with a sentence requesting the *dal* or the *bal*. These trials tested children's willingness to spontaneously interpret a novel neighbor as a novel word rather than a reference to a familiar pictured object.

Counterbalancing for target and picture side of presentation was as in Experiment 1. No more than two *both-novel* trials appeared consecutively. Target side did not repeat more than two times on consecutive trials. An approximately equal number of children were assigned to each order; half were taught a neighbor and half a nonneighbor. Girls and boys were assigned to neighbor and nonneighbor conditions nearly evenly (7 boys and 6 girls were taught a neighbor).

Coding—Videotapes were digitized to MPEG format and coded frame by frame as in Experiment 1. Reliability was established by re-coding 6 consecutive trials of 8 randomly selected subjects. Mean percent agreement was .973 and mean Cohen's kappa was .913.

Results

Response measures were computed as in Experiment 1. The first analyses concerned the *both-novel* trials, which served as the primary measure of children's learning of the taught word. In children hearing the novel nonneighbor, salience-corrected target fixations averaged 10.8% (SD = 11.7). In children hearing the novel neighbor, target fixations averaged 2.3% (SD = 10.9; see Figure 4). Only responses to the nonneighbors were significantly greater than zero ($t(13) = 3.44$, p(one-tailed) $< .005$).[8] The difference between these two conditions was significant ($t(26)= 1.98$, p(one-tailed) $< .05$). Thus, Experiment 2 replicated the main finding of Experiment 1, namely that children learned and identified the novel nonneighbor among the two novel objects, but did not do so with the novel neighbor.

Like Experiment 1, Experiment 2 also presented children with trials on which one picture was of a familiar object and the other a novel object (the *one-novel* trials). Children taught a nonneighbor were hearing a novel neighbor for the first time in these trials. Their response was to look at the familiar source word's referent (the distracter), as shown in Figure 4 (mean score, -19.2%, $t(13) = 5.66$, $p < .0001$). Thus, these children hearing a novel neighbor like *dal* treated it as an instance of *bal* (ball) and not as a name for the novel object. By contrast, children actually taught the novel neighbor did not show this response. When asked about the *dal* or *xond*, their salience-corrected fixations did not differ from zero (mean, -2.0%; $t(13) =-.39$, $p > .4$). Inspection of the distribution of individual children's means did not suggest a bimodal

[8]The use of one-tailed tests here reflects our testing a directional prediction from Experiment 1.

pattern; more than a third of these children's mean fixation proportions were between −0.10 and 0.10.

Turning to the *one-novel* trials in which a familiar word was spoken (rightmost pair of bars in Figure 4), children taught a non-neighbor were, as expected, well above chance levels in fixating the familiar source word's referent. Upon hearing *bal* or *hond*, they looked at the ball or dog (mean, 18.4%; $t(13) = 4.15$, $p(13) < .002$). However, children who had been taught the novel neighbors *dal* or *xond* performed at chance levels upon hearing these familiar words (mean, -5.3%; $t(13) = -.85$, $p > .4$). This result suggests that exposure to the novel word interfered with recognition of the familiar word, an effect discussed in more detail below.

The two groups of children who were taught neighbors or nonneighbors differed in their responses on the one-novel trials. When the familiar object was named, the nonneighbor-taught children performed significantly better than the neighbor-taught children ($t(26) = 2.76$, $p = .011$). Thus, the experience of having been exposed to the novel neighbor in the teaching phase *impaired* performance on the familiar source word. When the novel object was named, however, the neighbor-taught children performed better than the nonneighbor-taught children in the sense that they were much less likely to interpret the novel neighbor as if it were the familiar source word ($t(26) = 3.11$, $p < .005$).

Analyses of the *both-familiar* trials showed that both groups of children performed above chance levels. Children taught a nonneighbor fixated targets at 10.6% above salience baselines ($t(13) = 4.00$, p(one-tailed) $< .001$); children taught a neighbor fixated targets at 8.3% ($t(13) = 2.42$, p(one-tailed) $= .016$). These proportions were not significantly different from one another ($t(26) = .52$, ns). Thus, differences between children learning neighbors and nonneighbors cannot be attributed to individual differences in ability or interest in performing the fixation task.

The number of words each child was reported to say and understand was tallied from the parental responses on the CDI. Estimated receptive vocabulary sizes ranged from 0 to 417 (mean 167, SD 105); productive vocabulary sizes ranged from 0 to 172 (mean 53, SD 50). Vocabulary size was not correlated with performance on *both-novel* trials, whether vocabulary counts were log-tranformed or not (maximum correlation, .10, $p > .4$). Raw vocabulary size was weakly correlated with performance on filler trials: receptive vocabulary, $r = .332$ (p(two-tailed)$= .08$; productive vocabulary, $r = .389$, $p = .04$). Log-transformation of the somewhat skewed production vocabulary counts did not increase this correlation.[9]

Discussion

Experiment 2 replicated the main findings of Experiment 1, showing better learning of phonological non-neighbors than of neighbors. Because Experiment 2 used a between-subjects design in which children were taught either a phonological neighbor or a non-neighbor, we may conclude that children's difficulty in learning novel neighbors is not limited to situations in which two novel words are being learned in close succession.

In addition, children who heard the novel neighbors for the first time in the presence of the familiar source word's referent and an object whose name was unknown tended to interpret the novel word as a label for the familiar object. These results corroborate and extend the findings of Merriman and colleagues (e.g. Merriman & Schuster, 1991) who tested older children's performance in an analogous word-mapping task and found only intermittent use of a process-of-elimination strategy in interpreting novel neighbors and near-neighbors.

[9]Response latencies on *both-familiar* trials were negatively correlated with raw vocabulary counts, though these correlations were only marginally significant (receptive vocabulary, $r = -.302$, p(one-tailed) $= .06$; productive vocabulary, $r = -.271$, p(one-tailed) $= .09$).

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Children's failure to demonstrate a "mutual exclusivity" bias here suggests that their apparent success in differentiating (e.g.) a *tog* and a *dog* on the *one-novel* trials of Experiment 1 was not simply a reflection of children's ability to spontaneously determine that a novel neighbor is indeed a novel word that should be linked to a novel object (Halberda, 2003). Some prior exposure to the novel neighbor appears to be required (and may not even be sufficient, as seen in Experiment 2; see also White et al., 2004).

In Experiment 2, children's exposure to novel neighbors had strong effects on their interpretation of both the familiar source words (which were not successfully recognized by these children) and the novel neighbors (which were, at least, not simply interpreted as instances of the familiar source words). Children who had not been taught a novel neighbor readily treated (e.g.) *dal* as an instance of the familiar *bal*. Thus, children exposed to a novel neighbor in the teaching phase learned something. But what? The pattern of results in Experiment 1 suggested that at best, children had learned the phonological form of the novel word, but only a vague sense of its meaning that was equally compatible with each of the novel objects. Thus, they were at chance on the *both-novel* trials and above chance in determining that the novel neighbor did not refer to its familiar competitor. In Experiment 2, neighbor-taught children were less successful. Their responses on the *one-novel* trials suggested unresolved competition between interpretation of the novel word as referring to the novel object or to the familiar object.

Experiment 2 also revealed impaired recognition of the familiar source word among children taught a novel neighbor. Similar signs of lower performance on familiar source words was found in Experiment 1, where children's performance in recognizing these words was reduced on *one-novel* trials relative to *both-familiar* trials. This result was surprising given that the familiar words tested on these trials were among the words most children learn very early; if anything in the lexicon would be expected to be robustly encoded and relatively immutable, it would be items like *ball*.

One explanation for these results not requiring change in children's representations of familiar words is that children may have made a semantic overextension when being taught the novel neighbors. Upon hearing *xond*, children may have interpreted the speaker as labeling the dinosaur or manta-ray as a dog, perceiving the word as *hond*. If the novel object and the familiar object were considered to be members of the same category (i.e. the dinosaur is actually a dog), then each would have been a reasonable referent of the word *hond*, leaving children with no basis for choosing one object or the other on the *one-novel* trials. However, this explanation seems more sensible for the *hond/xond* pair than the *bal/dal* pair. A dinosaur or even a manta-ray might be a weird sort of dog, but these creatures are hard to conceive of as balls. On this semantic account, performance should have been better on the *bal* items than the *hond* items, and this was not the case. Thus, we consider it unlikely that children formed a large semantic category including both familiar objects (named by well-known words) and our novel objects.

A second possibility is that children's apparent confusion when queried about familiar source words stemmed from their experience on prior trials, in which they were repeatedly asked about the novel neighbor. After the teaching phase of the experiment, children received six *both-novel* trials asking for the novel object. Thus, when neighbor-learners came to the familiar-word *one-novel* trials, they had just heard either *xond* or *dal* twenty-two times (16 in teaching, 6 in testing), always used with reference to a novel object and without the familiar referent on the display. This may have biased children away from correctly interpreting (e.g.) *bal* as *bal* as much as they might have had they been given more balanced exposure. This account, if correct, requires no modification of either the semantic or phonological characteristics of children's lexical entries for the familiar words; it demands only that children's assumptions about the likely answers to our queries were weighted more strongly than their phonological categorization of the familiar words and novel neighbors.

General Discussion

The present experiments provide a first step in delineating the processes by which 1.5-year-olds learn new words, with respect to the balance between phonological sensitivity and toleration of sub-lexical variability. By 18 months of age children are generally agreed to be capable of discriminating the speech sounds of their native language, though often not the speech sounds of other languages. The effect of native-language exposure is usually held to reflect children's formation of language-specific phonetic categories. One implication of children's interpretation of speech in terms of these categories is that children (and indeed adults) should treat two words as the same if those words vary only along an undiscriminated (e.g., nonnative) phonetic dimension. This conclusion has substantial empirical support (e.g. Bosch & Sebastián-Gallés, 2003; Cutler & Otake, 2004; Pallier, Colomé, & Sebastián-Gallés, 2001).

Another implication of children's language-specific categorization is that they should treat two words as different if those words contain the sounds of a discriminated, native contrast. This implication does not hold consistently. In previous studies, we showed that children could distinguish (e.g.) *ball* and *gall* in a word recognition task (Swingley & Aslin, 2000); yet in the present experiments, interference from the familiar word prevented successful learning of the novel neighbor. Given that a word like *gall* leads children to think about and search for a ball, it seems likely that children hearing the novel neighbors in the teaching phase of the present experiments also activated (e.g.) *ball* and its denotation. This appeared to divert children's attention from the task of linking the novel sound-form to the displayed novel object.

Sound–Meaning Mappings

Some of the present findings suggested that children learned the sound-forms of the novel words, but not the connection between those forms and their referents. Thus, in Experiment 1, children could not pick out the novel neighbor's referent when it was paired with another novel object (they looked at a tog and meb equally upon hearing *tog*), but they scored above chance in identifying a novel object, not the familiar neighbor's referent, as the denotation of the novel neighbor (they looked at a tog more than a dog upon hearing *tog*). In Experiment 2, children who were taught a single novel neighbor did not achieve the latter result, but did at least avoid interpreting the novel neighbor as an instance of the familiar word when asked to distinguish (e.g.) a dog (*hond*) and a dinosaur (*xond*). The fact that children were at chance in this condition suggests that we observed word learning in progress: avoidance of the naive response, without correct identification of the referent. Our interpretation of this result is that while children's difficulties here had a phonological source, the locus of the problem was in linking the sound pattern with the novel object category and not in perceptual categorization of the speech stimulus. Further research would be required to establish this conclusively. It is important to note that each child heard only 16–20 instances of each novel word. More extensive exposure, which is typical of the natural listening environment for many words, would likely lead to more robust linkages between the novel auditory word-form and the novel referent (Swingley, under review).

Other studies have documented one-year-olds' failure to fully encode phonological properties of newly-learned words, including several studies of 14-month-olds by Werker and colleagues (Stager & Werker, 1997b; Werker et al., 2002). Stager and Werker (1997) emphasized attentional burdens that apply in word learning. If children's attempts to associate a syllable with an object demand scarce attentional resources, children may fail to completely encode the phonology of the syllable. According to Mills, Prat, Zangl, Stager, Neville, & Werker (2004), 14-month-olds can perceive the distinction between (e.g.) [b] and [d] while learning words, but fail to store the relevant phonetic features in memory.

Similarly, Swingley (2003) argued that young children can perceive speech in terms of language-specific phonetic categories, but may nevertheless fail to encode new words accurately, just as adults sometimes do (e.g. Smith, Macaluso, & Brown-Sweeney, 1991). The argument being advanced both by Werker and colleagues and by the present authors is that children's word learning performance is constrained by limitations related to phonology, and that these limitations are multifaceted. It is not the case that infants' or young children's discrimination performance or even their differential performance in word recognition tasks translates directly into perfect phonological categorization when competing factors come into play. Lexical competition is clearly one of these factors, and it is based, in part, on long-term memory of the sound patterns of words.

Some previous studies with older children have found better learning of words whose component sounds are frequent, where *frequency* is computed by taking into consideration both the position of the sound in the word, and the likelihood of adjacent sounds occurring together (e.g. Storkel, 2001, 2003; but see Storkel, 2004). Because words that have frequent sounds and sound combinations tend to be words having many neighbors, phonotactic probability effects can be difficult to disentangle from neighborhood effects (e.g. Vitevitch & Luce, 1999). To evaluate whether the present results might be better described according to phonotactic probability than the presence of familiar phonological neighbors, a range of phonotactic probability measures were computed over the eight words tested in the two experiments.

These analyses used corpora of infant-directed speech to measure the frequencies of sounds and adjacent sound pairs. Following Vitevitch and Luce (e.g. 1999), sounds were counted with respect to their position in the word; thus, to evaluate the frequency of the /ɡ/ in *gall*, the likelihood of /ɡ/ as the first sound in the words of the corpus was computed (not the overall frequency of /ɡ/). The English analyses used a half-million-word subset of the Brent and Siskind (2001) corpus, which was assigned estimated phonological transcriptions by substitution of each orthographic word with the first pronunciation of that word given in the Comlex English lexicon (Linguistic Data Consortium, 1997). Corpus words not in this dictionary were ignored (3.7% of tokens). In none of these analyses did children's word learning performance align with phonotactic probability measures; *meb* and *shang* were not found to be phonotactically more probable than *tog* and *gall*. For example, ranking the stimulus words by the mean probability of their component sounds produced the following order: *gall* (most frequent: .039), *meb* (.034), *shang* (.032), *tog* (.024). Ranking by the mean probability of the words' component bigrams (e.g. /mɛ/ and /ɛb/ of *meb*) produced the order *gall, shang, tog, meb*. Weighting these counts by the log frequency of each sound's host words in the corpus produced similar results.

Equivalent computations were performed over a 25,000-word corpus of Dutch infant-directed speech (Swingley, 2005b; van deWeijer, 1998). In these analyses, the neighbors tended to group together but with *higher* phonotactic probability than the nonneighbors, the reverse of what would be expected on the hypothesis that higher phonotactic probability caused better learning in the present studies. For example, ranking the stimulus words by mean probability of each component sound yielded the order *xond* (.107), *dal* (.066), *bemp* (.045), *biesh* (.035). Of course, it is possible that phonotactic probability influenced children's learning to some degree, but in the present experiments it is clear that effects of familiar neighbors (the familiar source words) dominated children's interpretation of these novel words.

Continuity during Development

It would be surprising if adult English speakers were to fail in the present *both-novel* and *one-novel* tasks. What are the crucial differences between 18-month-olds and adults? One obvious answer is that phonological categorization continues to improve not only from birth to 12 months, but throughout the first year and beyond. Studies testing children's recruitment and weighting of phonetic cues to phonological categories have confirmed that phonological perception develops throughout childhood (Nittrouer, 2002; Ohde & Haley, 1997). Perhaps children simply failed to correctly categorize the sounds in our novel words. We suspect that this is an important component of children's learning failures here, but only indirectly. The teaching and test stimuli were intentionally recorded as very clear phonological sequences, presented in isolation or sentence-finally in a careful "infant-directed" register. Though even 2- and 3-year-olds are not yet adultlike in their responses to conflicting or ambiguous acoustic cues to phonological categories, the present stimuli were clear, prototypical (or even a bit exaggerated) tokens and were probably categorizable as such had lexical competition not interfered.

However, children's experience with language certainly includes speech much less clearly articulated than the stimuli in these studies. The fact that in general children categorize speech less efficiently than adults (or at least do not weight phonetic cues as adults do) suggests that in their day-to-day processing of speech children may need to rely on top-down inference more than adults do. If this is true, children may rely extensively on prior linguistic knowledge (such as the stock of words in their vocabulary) even when the speech materials they hear are clear, as in the present circumstances. Put loosely, children may have learned not to trust their ears. Whenever children *mis*perceive the sounds in a parent's (correct) naming of a familiar object with a familiar word, they receive (false) evidence that phonological differences need not signal lexical differences. This observation suggests that children's reliance on a phonological criterion for creating new lexical entries should increase in tandem with improvement in phonological categorization of natural speech in general, not only categorization of clear cases.

Note, though, that young children's difficulties in speech categorization alone cannot account for the present results, since even 14-month-olds reliably find words like *tog* hard to recognize as *dog* even in the presence of a dog picture (Swingley & Aslin, 2002) and reject *ball* as a label for a doll (Fennell &Werker, 2003). It is not that one-year-olds are indifferent to phonological variation; rather, they do not readily interpret this variation as signaling a novel word. Using Werker's audio-visual habituation procedure, it is difficult to teach infants two similar words at 14 months; at 18 months, however, children succeed in differentiating two novel words. But as shown in the present pair of studies, 18 month olds fail to learn a word with an entrenched lexical competitor.

This latter result was contrary to our predictions, which favored phonological sensitivity over lexical stability. The 18-month-olds studied here will spend the next several years learning thousands of words, and might therefore be expected to be open to interpreting phonological variation as signaling a novel word (especially relative to adults, whose vocabularies are presumably more stable). As a result, children's resistance to word learning seems surprisingly maladaptive.

One possible solution to this puzzle is to suppose that young children know very few phonological neighbors, and consequently adopt an overly liberal similarity criterion when judging whether a word is familiar or novel. To take an extreme example, a child who knew only the words *shoe*, *baby*, and *dog* might assume that *tog* is an instance of *dog*, simply because the available evidence suggests that words are widely distributed in phonological space. Expansion in the vocabulary would provide evidence for tighter clustering and could lead children to re-estimate the likelihood that two similar word-forms indicate distinct words. A very similar proposal has been made by a number of researchers with reference to children's early lexical *representations*, rather than children's criteria for identifying novel words (e.g. Charles-Luce & Luce, 1990, 1995; Metsala & Walley, 1998; Storkel, 2002). According to these authors, children come to represent words in terms of discrete phonological segments as a consequence of crowding in phonetic space: if several words occupy a similar region, children attend more closely to the phonetic differences among these words, thereby enriching their knowledge of how those words sound.

We have suggested that in fact phonetic specification of young children's words is not contingent upon the presence of similar words in the vocabulary, because children are highly sensitive to mispronunciations of words that appear to have no neighbors (Swingley, 2003; but see Walley & Flege, 1999) and because mispronunciation sensitivity in 14 to 24 month olds is uncorrelated with vocabulary size and age (Swingley & Aslin, 2000, 2002). However, knowing that *tog* is a bad pronunciation of *dog* does not entail recognizing that *tog* is a different word. The latter would require the development of a phonological system that sets strict categorical criteria. It remains possible that this criterion is motivated by lexical crowding in phonological space. If children of about 18 months know few words that sound similar to one another, they might be more open to considering phonological variants as the same word.

Previous examinations of the neighborhood characteristics of young children's vocabularies have based their estimates on lists of words typically known by children (Charles-Luce & Luce, 1990; Dollaghan, 1994), words spoken by parents to their children (Charles-Luce & Luce, 1995; Coady & Aslin, 2003), or words spoken by two- to three-year-old children (Coady & Aslin, 2003). All of these studies have suggested that children know a substantial number of phonological neighbors; for example, Dollaghan's (1994) analysis of a 407-word list of words young children typically know revealed that 80% of these words were neighbors of at least one other word in the list. However, these studies may have overestimated the number of neighbors in the lexicons of individual 18-month-olds, either because they considered speech of older children and adults, or because they counted words that tend to be known by children in aggregate but which may not all be known by many individual children.

To address this issue, we computed the neighborhood characteristics of the receptive vocabularies of each of the Dutch children in Experiment 2. Parents' responses on all items of our 515-word adaptation of the MacArthur-Bates inventory were entered into a database. Pronunciations of each word were estimated from the Celex dictionary (Baayen, Piepenbrock, & Gulikers, 1995) and used to compute the neighborhoods of the words in each child's vocabulary, using the standard definition of *neighbor* as a word that can be converted into another word by addition, deletion, or substitution of a single speech sound (e.g. Luce & Pisoni, 1998). Stress and syllable boundaries were not marked; words were considered simply as linear strings of segmental categories. Morphological variants of the words listed on the inventory were not considered, for comparability with previous research and because the consequences of same-stem neighbors like *car* and *cars* may differ from those of different-stem neighbors like *car* and *card* (e.g. Morgan, April, 1998).

The results of this analysis showed that most words in each child's reported vocabulary had no phonological neighbors (mean proportion of "alone" words, 66.9%; SD, 8.5%; range 52.9 to 92.0). On average, about 14% of children's vocabularies were words having two or more neighbors. As expected, vocabulary size was negatively correlated with the proportion of words lacking neighbors ($r = -.782$, $p < .01$), showing that phonological space is particularly sparse in children who know few words. The fact that about a third of children's words had phonological neighbors indicates that even eighteen-month-olds require reasonably complete phonological representations to maintain full distinctiveness among the words in their vocabularies; however, many of the new words children are learning at this age have no familiar neighbors.

Children's apparent indifference to minimal phonological variation in the present study may also be related to their estimate of the likelihood that a novel *object label* will sound very similar to a familiar object label. Competition or interference between words may be greatest when those words are phonologically *and* semantically related. Although few phonological neighbors are synonyms, even partial overlap in semantic space could, in principle, exacerbate interference (Cabasaan & Woodward, 2003; Regier, 2003; see also Tenenbaum & Xu, 2000). A second analysis of the Dutch children's vocabularies revealed that 18-month-olds know very few pairs of neighboring object labels: using a broad definition of *object* (including words for snow and beverages, for example) the proportion of object words that had no phonological neighbors also referring to objects was 78.6% (SD = 7.7%; range 70.8 to 100). This may bias children away from interpreting novel neighbors of objects as new words for objects. These considerations suggest that children's interpretation of neighbors as familiar words may have some justification in the nature of children's linguistic knowledge. In Bayesian terms, the prior probability of a similar-sounding word referring to a new object is very small in early childhood lexicons.

We do not claim that children's behavior is *rational* or *ideal*. The novel words of the present studies were introduced in what should have been a very clear labeling context: a photographic image of a novel object (or the object's physical presence itself, in Experiment 1) was repeatedly accompanied by verbal descriptions like *This is a tog*. Children's failure to take this pragmatic naming context into account may indicate the greatest difference between 18-month-olds and adults. As described earlier, adults may fail to catch deviant pronunciations embedded in running speech even when instructed to do so (e.g. Cole, Jakimik, & Cooper, 1978). Adults may also be the source of popular folk etymologies such as referring to *asparagus* as *sparrowgrass* (Morris & Morris, 1988). Thus, adults too may be biased in favor of interpreting speech in terms of familiar lexical categories. The difference comes in the magnitude of the effects. When the speech evidence is suboptimal (as under normal conversational listening conditions), adults impose lexical interpretations that fit the semantic and phonological constraints of the situation. But even with very clear speech, children appeared to neglect the semantic and pragmatic demands of the sentences containing novel words. This result is particularly striking given that children understand other pragmatic or metalinguistic markers, such as those indicating repairs or speech errors, at the age of two years (Clark & Grossman, 1998; Tomasello & Barton, 1994; see also Clark &Wong, 2002). Clark and Grossman (1998) found that young two-year-olds understand adults' verbal guidance about word meanings, in utterances like “A *dob* is a kind of *ruk*.” Perhaps young children would interpret a word like *tog* as a distinct word if explicitly told that *togs* are different from *dogs*. But they do not draw this inference spontaneously based on the phonological difference alone.

Summary and Conclusions

We have suggested three processes in which developmental changes would be expected to alleviate children's difficulties in learning novel neighbors: enhanced phonetic sensitivity, perhaps leading to greater weighting of speech information in children's interpretation; the development of a phonological criterion for differentiating words, possibly under the influence of crowding in the vocabulary; and improved appreciation of pragmatic cues pointing to the introduction of novel words. These processes are not mutually exclusive; all might contribute. In addition, their effects on children's word learning may be indirect, feeding into the child's subjective sense of language in general as clear, specific, and readily comprehensible—or obscure, vague, and understandable only with effort. If the child's experience of linguistic interaction is frequently one of guesswork and problem-solving, he or she may try to make do with the available words simply because permitting the postulation of novel words or other structures removes too much constraint on interpretation. This could result in a bias in favor of familiar-word interpretations even when the phonology does not match exactly, and even when from the adult's perspective the conversation is explicitly about the teaching of a new word.

Anecdotal reports show that neighbor confusions in word learning are not restricted to laboratory conditions. For example, Gelman reports an instance in which her 16-month-old daughter appeared to interpret the *pinecone* as a kind of comb (2003, p. 57). Similarly, at 24 months, the first author's son, watching eggs being cooked, interpreted his mother's (French) phrase *les oeufs* (/lezø/, "the eggs") as *les yeux* (/lezjø/, "the eyes").[10] In these cases the conflated phonological neighbors shared some semantic or perceptual properties (see also Gopnik & Meltzoff, 1997, p. 28). The present studies have shown that this is not a necessary condition, but the examples suggest that children are motivated to make sense of the discourse while minimizing the conjecture of novel linguistic units.

The present results suggest a word-learning analogue to the *lexical competition* effects found in studies of adult word recognition. Other factors being held equal, words that sound similar to many other words are recognized more slowly than words that have few neighbors (e.g. Luce & Pisoni, 1998), even under ideal listening conditions where phonological perception *per se* is presumably successful. These effects reflect the general principle that perceptual identification is more difficult when choosing from among many similar alternatives (e.g., Usher & McClelland, 2001). In the word-recognition literature, where the term *competition* is used to describe this phenomenon, such effects are often considered a consequence of inhibitory connections between words (e.g. McClelland & Elman, 1986; see also Gaskell & Marslen-Wilson, 2002). Lexical competition effects resemble the present interference effects in that in both cases, words that are phonologically similar to another spoken word affect that word's interpretation. In adults, competition slows processing and may make recognition somewhat less accurate; in children, interference apparently can prevent successful word learning.

A number of questions about these effects remain to be examined. One concerns the amount of phonetic or conceptual overlap between the novel and familiar neighbors that is sufficient for causing confusions. It seems likely that these two different sorts of overlap trade off (Cabasaan & Woodward, 2003; Regier, 2003, 2005). Similarly, it is not known at present how best to define the similarity space over which overlap among words is computed (e.g. Bailey & Hahn, 2001; Treiman & Breaux, 1982). Finally, the age at which children achive a more adultlike criterion for postulating new words is uncertain; for example, it is possible that 24-month-olds tested under the same conditions would succeed in learning novel neighbors. An important question to address in tracing the course of development is whether children become less willing to accept phonological variants of words in a general way, or if this learning proceeds contrast by contrast. For example, did the Dutch learners fail to treat *xond* as novel because they knew few word pairs varying only in onset /h/ and /x/? Parental reports on the CDI checklist indicated that only a minority of Dutch participants knew minimal pairs like *hoed–goed* ("hat–good"), *bad–dat* ("bath–that"), and *boos–doos* ("angry–box"), which draw upon the tested phonological contrasts. But the CDI is missing frequent minimal pairs that many children this age do say, including *heeft–geeft* (3rd person of "have" and "give"), *haan–gaan* ("hen"–plural "go"), and *hele–gele* ("whole–yellow"; Fikkert, 1994; Levelt, 1994). Because these words are all quite frequent, we suspect that for the tested children as well, these contrasts do bear some functional load in the lexicon; that is, the tested contrasts are needed for distinguishing words children know. It is nevertheless possible that phonetic category distinctions are more likely to be considered relevant for lexical differentiation if those distinctions separate many words in the child's vocabulary, not just a few.

Most research on word learning has focused on children's developing capacity to align their interpretation of a word's meaning with the adult denotation (Bloom, 2000; Woodward & Markman, 1998). The present results highlight the complexity of the problem children face in building a lexicon by raising the additional issue of how children recognize that a new word

[10]This error was revealed when he turned to his father and translated, "Eyes!".

is being presented in the first place (see also Marazita & Merriman, 2004). We found here that in spite of infants' remarkable skills in phonetic categorization (e.g. Kuhl, 2004) and word recognition (Fernald et al., 1998), children have not "solved" the problem of speech perception by 18 months. During the second year, words and speech sounds are still gradually becoming entrenched as perceptual categories. Relating the phonetic and lexical levels of linguistic analysis according to the phonological criterion required by the language demands additional refinement in the interpretation of phonetic variability, and in the evaluation of the contexts in which parents introduce new words.

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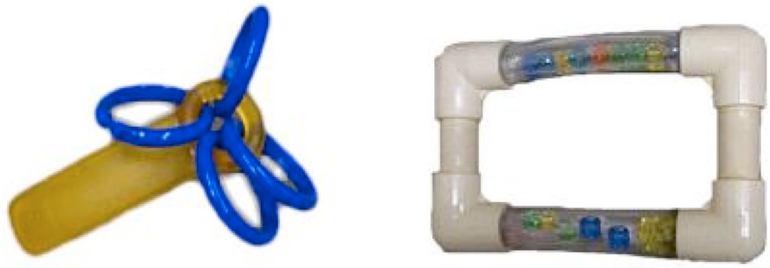

Figure 1.
Novel objects used in Experiment 1.

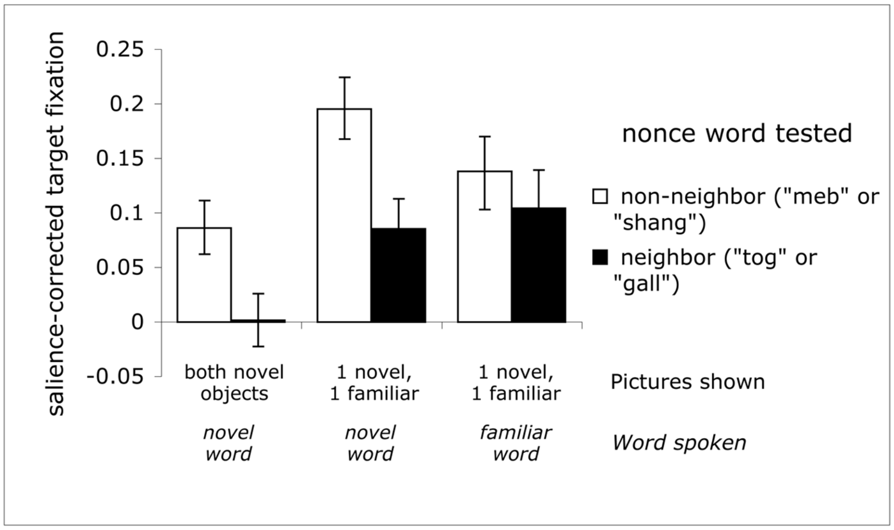

Figure 2. Results of Experiment 1: Children's salience-corrected proportions of fixation to the target picture

Bars show means over all children. Shading indicates whether the tested word was a phonological non-neighbor or a neighbor. The first pair of bars shows target fixation on *both-novel* trials, on which the two novel objects were displayed. The second and third pairs of bars show target fixation on *one-novel* trials, on which one familiar object and one novel object were displayed. On *one-novel* trials the children performed above chance upon hearing novel words (middle two bars) and familiar words (rightmost bars), and on both neighbors and non-neighbors, though performance was significantly better on novel non-neighbors than on novel neighbors. Error bars are standard errors.

Figure 3.
Novel objects used in Experiment 2.

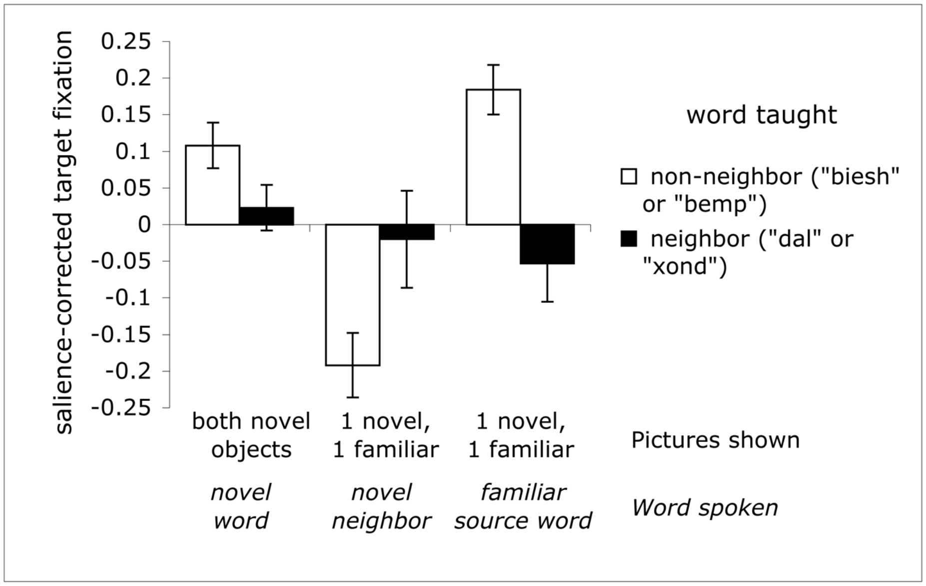

Figure 4. Results of Experiment 2: Children's salience-corrected proportions of fixation to the target picture

Shading indicates subject group: those taught a non-neighbor or a neighbor. The first pair of bars shows target fixation on *both-novel* trials, on which two novel objects were displayed. The second and third pairs of bars show target fixation on *one-novel* trials, on which one familiar object and one novel object were displayed. The *one-novel* results show that children taught a neighbor divided their fixation time equally between target and distracter, while children taught a non-neighbor fixated the familiar object: the distracter on one-novel novel-word trials and the target on one-novel familiar-word trials. Error bars are standard errors.

Table 1

Test trials for children taught *tog* for the bottle-opener, and *meb* for the rectangle

condition	qty.	pictures [T=Target]	spoken target
both-novel; test novel neighbor	3	bottle-opener T, rectangle	“tog”
both-novel; test novel non-neigh.	3	bottle-opener, rectangle T	“Meb”
one-novel; test novel neighbor	2	bottle-opener T, dog	“tog”
one-novel; test novel non-neigh.	2	rectangle T, car	“meb”
one-novel; test famil. source word	2	bottle-opener, dog T	“dog”
one-novel; test famil. non-neigh.	2	rectangle, car T	“car”

Sample trial types in Experiment 1. Trial structure for the children taught *tog* and *meb* for the bottle-opener and rectangle. Other children were taught *gall* and *shang*. The horizontal line divides the first and second trial blocks; trials were quasirandomly ordered within blocks. Eleven additional “both-familiar” filler trials, not shown here, displayed pairs of familiar objects and named one of them using its appropriate label. “Both-novel” and “one-novel” refer to whether the displayed pictures included two novel objects, or one. *Neigh.* abbreviates *neighbor* and *famil.* abbreviates *familiar*. The number of trials of each type is given under “qty.” Children taught *gall* and *shang* were tested on one-novel trials picturing a ball or a baby rather than a dog or car.

Table 2

Test trials for children taught a novel neighbor, *dal*, for the dinosaur

condition	qty.	pictures [T=Target]	spoken target
both-novel; test novel neighbor	6	dinosaur T, ray	"dal"
one-novel; test novel neighbor	5	dinosaur T, ball	"dal"
one-novel; test famil. source word	5	dinosaur, ball T	"bal"
Test trials for children taught a novel non-neighbor, *bemp*, for the ray			
condition	**qty.**	**pictures [T=Target]**	**spoken target**
both-novel; test novel non-neighbor	6	ray T, dinosaur	"bemp"
one-novel; test mutual exclusivity	5	dinosaur T, ball	"dal"
one-novel; test famil. source word	5	dinosaur, ball T	"bal"

Sample trial types in Experiment 2. Trial structure for the children taught *dal* for the dinosaur (upper half) or *bemp* for the ray (lower half). Other children learned *xond* or *biesh*. The horizontal line divides the first and second blocks. Twelve additional "both-familiar" filler trials displayed two familiar objects and named one of them. "Both-novel" and "one-novel" refer to whether the displayed pictures included two novel objects, or one. *Famil.* abbreviates *familiar*. The number of trials of each type is given under "qty." The novel word *dal* is a neighbor of Dutch *bal*, "ball." Note that block 2 for children taught a neighbor (upper half of table) tests the phonological specificity of the learned word, whereas block 2 for children taught a nonneighbor (lower half) probes children's spontaneous application of mutual exclusivity upon hearing a novel neighbor for the first time.