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Increasing Flexibility in Children's Online Processing of Grammatical and Nonce Determiners in Fluent Speech

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Abstract

Two experiments using online speech processing measures with 18- to 36-month-olds extended research by Gerken & McIntosh (1993) showing that young children's comprehension is disrupted when the grammatical determiner in a noun phrase is replaced with a nonce determiner (*the car* vs. *po car*). In Expt. 1, 18-month-olds were slower and less accurate to identify familiar nouns on nonce-article than grammatical-article trials, although older children who produced determiners in their own speech showed no disruption. However, when tested on novel words in Expt. 2, even linguistically advanced 34-month-olds had greater difficulty identifying familiar as well as newly learned object names preceded by a nonce article. Children's success in "listening through" an uninformative functor-like nonce syllable before a familiar noun was related to their level of grammatical competence, but their attention to the nonce article also varied with lexical familiarity and the overall redundancy of the processing context.

The article *the* is one of the words English-learning children hear most frequently, but it is never one of the first words they learn to speak. The observation that children can produce dozens of nouns before they begin to use determiners such as *the* or *a* led researchers to question whether spontaneous speech really captures what children "know" about language. Shipley, Smith, and Gleitman (1969) first addressed this question experimentally, asking whether children would reveal an early awareness of linguistic regularities by noticing syntactic anomalies in the speech they heard. Children whose own 'telegraphic' speech contained no determiners or other grammatical function words heard requests in which articles were either missing or replaced with a nonsense word, as in *Throw ball* or *Throw ronta ball*. The finding that 19- to 32-month-olds responded less coherently to such requests than to the grammatically correct version *Throw me the ball*, suggested that children at this age were indeed attentive to articles (Petretic & Tweney, 1977). Gerken and McIntosh (1993) pursued this issue with a more rigorous experimental design, asking how 2-year-olds used their implicit knowledge of determiners in interpreting content words in continuous speech.

Here we have extended these findings using online techniques for monitoring children's interpretation of spoken sentences (e.g., Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998). Although studies using offline measures can tell us whether children attend to the determiner at all in interpreting an utterance, they reveal nothing about the time course of processing. In Experiment 1 we examined the nature and timing of disruption that results when children encounter an anomalous article before a familiar noun. We also investigated developmental changes in children's responses to grammatical and nonce articles across the second and third year. As children grow older and begin to use determiners in their own

speech, do they become more flexible or less flexible in processing anomalous elements in the speech they hear? In Experiment 2 we increased the demands of the processing task by testing linguistically more advanced children on novel object names as well as familiar words, to determine whether the familiarity of the target word and the overall predictability of the processing context would affect children's responses to anomalous elements in the speech stream.

There are several reasons why children might omit articles from their early speech productions. In languages as different as English, Turkish, and Mandarin, determiners and other grammatical function words typically have shorter vowel duration and lower amplitude, with fewer syllables and simpler syllable structure, as compared to content words such as nouns and verbs (Shi, Morgan, & Allopenna, 1998). The low salience of function words was one reason why early investigators proposed that infants might simply fail to perceive or represent determiners in the speech they heard (Shipley et al., 1969). But when asked to imitate sentences that contained either English function words and morphemes or phonologically comparable nonce words and morphemes, 2-year-olds were more likely to omit the familiar grammatical words while preserving the nonce words, indicating that they could indeed distinguish among them (Gerken, Landau, & Remez, 1990). One explanation is that children's frequent omissions of determiners in spontaneous speech results from phonological limitations or difficulty in mastering the timing relations in speech production (e.g., Gerken, 1994a, b). Content words are semantically as well as phonologically more salient than grammatical words, another possible reason for young children's selective omission of functor words in early speech. Starting out with content words that refer to objects and actions rather than uneventful functor words like determiners, children can communicate effectively even in the one-word stage: "Cookie!" works well as a request, while "The!" does not. Since grammatical words are relational, children also need some understanding of the relations they specify before beginning to use such words (Gentner & Boroditsky, 2001). Proficient use of *the* and *a* requires competence on several levels, and appreciating the subtleties of definite and indefinite reference involves perspective-taking skills that take years to develop (Maratsos, 1974).

Despite the complexities on various levels involved in mastering the use of determiners, articles also serve a morphosyntactic function that may be more transparent to the linguistic novice, i.e., marking the beginning of a noun phrase. One corpus analysis showed that when *the* occurred in child-directed speech, a noun followed directly 93% of the time (Thorpe & Fernald, 2006). If children notice that certain words are followed by object names, then encountering *the* in the speech stream could lead to expectations about what kind of word might be next in line. The idea that attending to the co-occurrence of determiners and object names in speech might facilitate learning about nouns as a grammatical category was proposed years ago (Maratsos & Chalkley, 1980; Bloomfield, 1933), and recent analyses of child-directed speech provide support for the claim that common lexical patterns, often involving function words, provide information that language learners could use to classify words into syntactic categories (e.g., Mintz, 2003). Moreover, there is now abundant evidence that infants use prosodic and distributional information to identify recurrent sound patterns in speech (e.g., Jusczyk & Aslin, 1995; Saffran, Aslin, & Newport, 1996), and a few studies have examined early sensitivity to grammatical words in particular. Shi, Werker, and Morgan (1999) found that newborns can discriminate isolated lexical words from grammatical words based on acoustic characteristics. An early awareness of the phonological characteristics of grammatical words may provide a foundation for the increasingly differentiated forms of distributional learning that begin to emerge later in the first year (e.g., Höhle & Weissenborn, 2003; Höhle, Weissenborn, Kiefer, Schulz & Schmitz, 2004). By 11 months, infants are attentive to prosodic and segmental features of functor words in fluent speech (Shady, 1996; Shafer, Shucard, Shucard, & Gerken, 1998),

and by 18 months, they distinguish passages in which familiar functors are grammatically or ungrammatically positioned (Santelmann & Jusczyk, 1998).

Such studies using habituation or preferential listening methods can indicate whether and when infants are able to differentiate sequences of content and grammatical words based on perceptual characteristics or familiarity with distributional patterns. However, they do not reveal how this knowledge is put to use, e.g., how children begin to interpret determiners in relation to nouns as they make sense of noun phrases in continuous speech. Gerken and McIntosh (1993) addressed this question with 23- to 28-month-olds by manipulating the functor words preceding familiar object names. In a picture book task, children responded to requests in which the functor was either grammatical (*Find the ball for me*), ungrammatical (*Find was ball for me*), missing (*Find ball for me*), or replaced by a nonce syllable (*Find gub ball for me*). Accuracy was highest when the picture name was preceded by a grammatical article and lowest when preceded by a nonce word, with the other conditions falling in between. These findings not only confirmed that 2-year-olds attend to the sentence context in which determiners occur, but also revealed that a violation of the determiner/noun pattern could disrupt the process of sentence interpretation.

In Experiment 1 we extended the findings of Gerken and McIntosh (1993) [G&M] by examining the time course of interpretation when children encounter an anomalous word preceding a familiar object name. Is processing affected immediately, interfering directly with recognition of the target noun that follows? Or do children identify the target word successfully but then experience subsequent confusion given the oddness of the sentence? To address this issue, we used online rather than offline measures of speech processing. While offline measures test comprehension after the sentence is complete, online measures assess understanding as the sentence unfolds. Eye-tracking techniques that monitor how listeners scan a scene in response to relevant speech are now used extensively in research with children as well as adults (e.g., Trueswell, Sekerina, Hill, & Logrip, 1999; Swingley & Aslin, 2002). Fernald et al. (1998) found that infants orient rapidly to a picture matching a familiar spoken word and by two years of age begin to interpret speech incrementally (Swingley, Pinto, & Fernald, 1999; Fernald, Swingley, & Pinto, 2001). The first goal of Experiment 1 was to use online measures to confirm that young children's success in target word recognition is disrupted by a nonce article¹ and also to examine when such disruption occurs.

The second goal of Experiment 1 was to expand the age range of this research beyond the 23- to 28-month-olds studied by G&M (1993), including children from 18 to 36 months who also vary in their ability to use determiners in their own speech. One prediction is that as children begin to produce articles around 24 months, they become increasingly attentive to grammatical patterns, and thus are more sensitive to any violation of familiar determiner-noun sequences in the speech they hear. An alternative prediction is that vulnerability to disruption should *decrease* rather than increase with more advanced linguistic competence, as children by the age of three come to represent the grammatical category of determiners at a more abstract level (Pine & Martindale, 1996; Abu-Akel, Bailey, & Thum, 2004; Kemp, Lieven, & Tomasello, 2005). G&M began to explore this question, but with ambiguous results. However, in a later study also using offline methods, they found that typically developing 4-year-olds showed no disruption when the familiar noun label was preceded by a nonce functor (McNamara, Carter, McIntosh, & Gerken, 1998), suggesting that more

¹Nonce syllables are referred to as ungrammatical or anomalous 'articles', although we do not imply that children have analyzed them as such. Rather, this denomination is based on the distributional characteristics of the nonce syllables; i.e. their occurrence in article slots. Similarly, the terms 'functors' or 'function morphemes' have been used when referring to nonce syllables that appear in pre-nominal article positions without regard to the child's understanding of their grammatical function (Gerken & McIntosh, 1993; Shi, Werker, & Cutler, 2006).

linguistically advanced children can ignore such anomalous elements. To explore this question further, we analyzed the data from Experiment 1 in two different ways. In one set of analyses, children were grouped by age (18, 24, and 36 months). In a second set of analyses, we compared children who were not yet using determiners in their own speech with those who produced determiners, given recent research showing that children's efficiency in online speech processing is associated with their level of grammatical competence (Fernald, Perfors, & Marchman, 2006; Lew-Williams & Fernald, 2007).

Experiment 2 extended the results of the first experiment by testing 34-month-olds in a more challenging processing task that involved novel as well as familiar object names. Studies of speech production have shown that children who can produce grammatical words reliably in the context of well known content words often omit functors with less familiar words (e.g., Bloom, Miller, & Hood, 1975). Using an elicited imitation task, Boyle and Gerken (1997) found that lexical familiarity influenced young children's tendency to omit grammatical functor words. When the sentence contained a novel or unfamiliar noun, 2-year-olds were more likely to omit the preceding determiner than when the noun was familiar (e.g., *He's breaking the stick/twig/kad*). Does lexical familiarity affect children's receptive processing of determiners, just as it affects speech production? To explore this question, in Experiment 2 we tested the hypothesis that a nonce article would be more disruptive in the context of a newly learned novel word than in the context of a highly familiar object name.

EXPERIMENT 1

In Experiment 1 we replicated and extended the findings of the G & M (1993) study using online measures with children across a wider age range. In addition to these changes, we modified four other features of the original G&M paradigm that may have influenced their results. First, the nonce word *gub* ends with a consonant, atypical of English articles; thus children might have performed better if a more representative CV syllable had been used instead. Second, target nouns occurred in medial position, potentially less accessible than they would be in the sentence-final position typical of speech to children (Fernald & Mazzie, 1991; Fernald, McRoberts, & Swingley, 2001). Third, some of the target words were not well known by children in the age range studied (e.g., *kite* and *couch*). Finally, the synthetic speech stimuli might have sounded somewhat unnatural. To address these concerns, we replaced the determiner *the* with four different CV syllables that were acoustically more similar to English functor words than the CVC nonce syllable used by G&M. We also used naturally spoken target words in sentence-final position, all reported by parents to be familiar to the participants.

Experiment 1 addressed three main questions: First, when tested in an online procedure, are children less reliable and slower to recognize familiar object names if the article preceding the target word is replaced by a nonsense syllable or is absent altogether? And if so, does a nonce article interfere immediately with processing, or does the child identify the target word but then respond subsequently to the "oddness" of the ungrammatical sentence? Second, does the extent of such disruption increase or decrease between the ages of 18 and 36 months? And third, are children who produce determiners in their own speech more or less likely to experience disruption when they encounter a nonce article?

Method

Participants—Participants were 98 children from 18 to 36 months ($M = 2;2.5$, range: 1;6.0 to 3;1.7). Half the children were female. Twelve additional children were excluded because of fussiness (11), or exclusive side bias (1). All participants were from families in which English was the primary language. For analyses by age, the sample was divided into three groups: 34 18-month-olds ($M = 1;6.14$, range: 1;6.0 to 1;6.28), 34 24-month-olds ($M =$

2;0.15, range: 2;0.0 to 2; 0.29), 30 36-month-olds ($M = 3;0.16$, range: 2;11.2 to 3;1.7). For analyses by determiner production, the sample was divided into two groups based on parental report of children's use of determiners in speech production: 53 children who did not yet produce determiners, and 45 children who produced determiners. This classification was derived from the example sentences parents provided when asked to list the "longest sentences you've heard your child say recently" on the MacArthur-Bates Communicative Development Inventory (Fenson et. al., 1993). Children were placed in the determiner-producer group if at least one of those example sentences contained the article *the* in an obligatory context. For 87% of the children in this group, their reported longest sentences also included examples of determiners such as *a*, *this*, *that*. Children were placed in the determiner-non-producer group if none of their longest utterances contained a determiner, or if their parents reported no use of multiword utterances. The mean age was 1;8.24 (range: 1;6.0 to 2.0.29) in the determiner-non-producer group, and 2;8.16 (range: 2;0.1 to 3;1.7) in the determiner-producer group.

Speech stimuli—Stimulus sentences contained one of eight target words (*kitty*, *doggie*, *birdie*, *baby*, *car*, *ball*, *shoe*, *book*) understood by all participants according to parental report. Each target word was used in all three determiner conditions:

1. grammatical article (e.g., *Look at the shoe.*)
2. nonce article (e.g., *Look at loo shoe.*)
3. no article (e.g., *Look at shoe.*)

The nonce articles consisted of four consonant-vowel syllables (/ko/, /pɔ/, /ri/, and /lu/) resembling English articles in that they were short and unstressed. However, they had full rather than reduced vowels so they would not rhyme with *the* and *a*.² Nonce articles were paired with target words as follows: /ko/ *doggie* and *baby*; /lu/ *shoe* and *ball*; /pɔ/ *book* and *car*; /ri/ *birdy* and *kitty*.³ Four carrier frames (*Where's_*; *Find_*; *Show_*; *Look at_*) were each used with two target words in each condition.

Multiple tokens of each sentence were recorded by a female native speaker of English, then digitized (44 kHz with 16-bit quantization), acoustically analyzed, and edited using *Peak* 2.61 LE sound-editing software on a Macintosh computer. To identify candidate stimuli most closely matched in prosodic characteristics, we measured the duration of each carrier frame, article, and target noun. Choice of final stimuli was governed by three considerations: First, all carrier frames were matched in duration ($M = 269$ ms; range: 261 to 278). Second, grammatical and nonce articles were matched in duration: grammatical ($M = 160$ ms; range: 147 to 172); nonce ($M = 168$ ms; range: 156 to 172). It was also important that all articles be unstressed, and to the same degree. When rated by two listeners, trained in phonetic analyses and blind to the hypothesis, both sentence types were judged to be comparable in intonation contour and in their overall naturalness. To ensure that each target noun was acoustically identical across conditions, a single token of each was cross-spliced into carrier frames in all three determiner conditions. Mean duration of the eight target word tokens in the final stimulus set was 527 ms (range: 445 to 552). Two listeners rated all cross-spliced sentences for naturalness. Mean duration of the stimulus sentences was 978 ms (range: 820 to 1068

²Although the two English articles *a* and *the* are typically spoken with a reduced vowel, many determiners are not (e.g., *this*, *that*, *these*, *those*); thus determiners with full vowels are common in children's experience. Gerken and McIntosh (1993) used a CVC syllable with a reduced vowel as their nonce determiner. However, other related studies using nonce functors with full vowels have found comparable results (e.g., Shafer et al., 1998). In a direct comparison of infants' responses to nonce functors with full versus reduced vowels, Shady (1996) found that 10-month-olds discriminated grammatical functors from nonce functors regardless of vowel quality.

³For ease of reading, the four consonant-vowel non-words will be shown in the International Phonetic Alphabet Code only when describing the speech stimuli and will otherwise be shown in standard English orthography.

ms). There were 24 experimental trials, 8 in each determiner condition. Eight filler sentences were included to maintain interest, resulting in a total of 32 trials.

Visual stimuli—Visual stimuli were colorful digitized images of the objects named by the target words, with three different tokens for each type. Images were presented in yoked pairs (*baby/doggy*, *birdy/kitty*, *car/book*, *ball/shoe*) approximately matched in size and brightness.

Apparatus—The looking-while-listening-procedure (Fernald et al., 2006; Fernald & Hurtado, 2006) was conducted in a three-sided booth. In the front panel, two 25 cm × 19 cm color monitors were mounted side by side (60 cm apart on center). Speech stimuli were delivered through loudspeakers below the monitors. The child sat on the parent's lap facing the monitors at a distance of 88 cm. A curtain behind the child's head blocked the parent's view of the monitors. A video camera focused on the child's face was connected to a video-recorder in an adjacent control room, where the computer controlling the experiment was also located.

Procedure—When the child was attentive, lights were dimmed and an experimenter in the control room spoke over the loudspeaker to familiarize the child with the sound source before starting the experiment. On each trial two pictures were shown for 2 s prior to presentation of the speech stimuli. Trial types were presented in a quasi-random order, with each object appearing as target and distracter equally often on left and right sides in each condition. Children were randomly assigned to one of two stimulus orders. Trials were separated by 800 ms when both screens were blank. The experiment lasted 4 min.

Coding eye movements—The video record was stamped with a time code (33 ms resolution) and digitized using *Adobe Premiere* software. In offline coding, highly trained observers blind to trial type and target location coded the gaze patterns frame-by-frame, noting on every frame whether the child was fixating the left or right picture, moving between pictures, or away from both. Eye movement data were coordinated with information about target word onset on each trial, using custom software. For 25% of the participants, eight trials on which two or more gaze shifts occurred, were independently coded by two coders, and the primary coder's judgment served as data for all the analyses. Two measures of inter-observer reliability were calculated. The first was the proportion of frames on each trial on which coders agreed within a single frame; agreement was 98.8%. Since this analysis included many frames on which the child was simply maintaining fixation on one picture, a more stringent test of reliability was also used. This focused only on the most critical points in each trial, where the child shifted from one picture to the other, ignoring steady fixations in which agreement was inevitably high. By this more conservative measure, agreement within one frame was 96.9%.

Measures of efficiency in online word recognition—The child cannot know in advance which picture will be named on any trial, and so by chance is equally likely to be looking at the target or the distracter picture at target word onset. Thus two kinds of correct responses are possible: if the child happens to be looking already at the matching picture (target-initial trials), she should continue to do so upon hearing the target word; however, if the child is looking to the distracter picture (distracter-initial trials), she should quickly shift gaze to the target picture upon hearing the target word. Three measures assessed children's efficiency in interpreting the spoken sentence: *Accuracy* and *reaction time* reflect how reliably and quickly children oriented to the correct picture; *shift-backs* reflect children's tendency to shift back and forth between pictures across the trial in situations of uncertainty, an index of disruption in processing.

Reaction time (RT)—Mean RT to identify the target word was calculated based on distracter-initial trials on which the first shift to the named picture occurred within the 367–1800 ms window from target word onset. Shifts to the target prior to 367 ms were excluded because they presumably occurred before the child had had time to process sufficient acoustic input and mobilize an eye movement (Haith, Wentworth, & Canfield, 1993). Determination of the lower cutoff point in previous studies has been based on estimates of the minimum time it takes listeners at different ages to process adequate phonetic information from the relevant word and then to launch an eye movement to the correct referent. In previous studies using eye-tracking methods, this cutoff has varied from 200–400 ms (e.g., Fernald et al., 2001; Bailey & Plunkett, 2002; Swingley & Aslin, 2002) with shorter intervals typically used with adults (e.g., Tanenhaus, Magnuson, Dahan, & Chambers, 2000) and children older than 24 months (e.g., Fernald et al., 2006). On the upper end of the time window, first shifts occurring between 1833–3000 ms from target word onset were excluded from RT analyses because these delayed shifts were considered as outliers less clearly in response to the target word (see Fernald et al. 2001).

Accuracy—Accuracy was operationalized as time spent looking at the target picture as a proportion of total time spent on either the target or distracter picture, averaged over the 367–1800 ms window following target word onset.

Shift-backs—This measure was used to explore whether disruption in response to nonce articles occurred not because children failed to identify the target noun efficiently, but rather because the oddity of the utterance caused subsequent confusion. In this case, children would be more likely to shift back and forth between pictures in the nonce-article condition than in the grammatical-article condition, reflecting greater uncertainty. Shift-backs were assessed over a window extending to the end of the trial 3000 ms from target word onset. This window captured second shifts following an initial correct response on distracter-initial trials, as well as incorrect shifts to the distracter on target-initial trials.

Results

Analyses by age group—Figures 1A–C show the time course of orienting to the correct picture when children are grouped by age, giving an overall picture of responses to the same familiar target words in each determiner condition. The curves depict changes in the proportion of total trials on which 18-, 24-, and 36-month-olds looked at the correct picture at every 33 ms interval as the stimulus sentence unfolded. Children were initially at chance at target noun onset in all conditions. In Fig. 1A, variations in slope and asymptote among the curves suggest that 18-month-olds responded differentially to target words in the three determiner conditions. In contrast, the high degree of overlap among the curves in Figure 1C indicates that 36-month-olds were equally efficient in recognizing the target noun in all three conditions. Note also the gradual increase in response speed and overall accuracy across age groups.

Mean accuracy scores were compared in a 3 (age) $\times$ 3 (determiner type: grammatical-, nonce-, no-article) mixed ANOVA. The main effect of age was significant, $F(2,188) = 33.61, p < .0001$, reflecting the increase in overall accuracy from 18 ($M = .62, SD = .13$) to 24 ($M = .68, SD = .14$) to 36 months ($M = .80, SD = .11$). The main effect of determiner type was also significant, $F(2, 188) = 3.25, p < .05$. Although mean accuracy scores were similar in the grammatical-article ($M = .71, SD = .13$) and no-article ($M = .70, SD = .15$) conditions ($p > .05$), children were significantly less accurate in the nonce-article condition ($M = .67, SD = .16$) than in the grammatical-article condition ($p < .01$). These results replicate two main findings of the original G & M (1993) study: first, that the efficiency of children's processing was significantly impaired when the familiar target noun was preceded by a

nonce article as compared to a grammatical article, and second, that no disruption occurred on no-article trials. Thus, the main effect of determiner type on accuracy derived primarily from disruption on nonce-article trials.

We next examined whether response speed was also affected by determiner type. Note that a reaction time can only be calculated on those trials on which the child starts out on the distracter and initiates a correct shift to the target picture as the target word is heard. Because these factors are not under experimental control and the total number of usable trials in each condition is small, eight children with missing cells in one or more conditions could not be included in these analyses. Mean RTs were compared in a 3 (age) $\times$ 3 (determiner type) mixed ANOVA. Speed of word recognition improved with age, with a significant decrease in mean RT from 18 ($M = 868$ ms, $SD = 236$) to 24 ($M = 834$ ms, $SD = 222$) to 36 months ($M = 740$ ms, $SD = 227$), $F(2, 172) = 5.39$, $p < .006$. Mean RTs were nearly identical in the grammatical-article ($M = 806$ ms, $SD = 236$) and no-article ($M = 809$ ms, $SD = 261$) conditions. Although children responded more slowly overall on nonce-article trials ($M = 835$ ms, $SD = 202$), neither the main effect of determiner type nor the interaction with age was significant.

The central interest in Experiment 1 was the comparison between the grammatical- and nonce-article conditions. However, we also included a no-article condition to enable comparison with results from previous studies using offline procedures. Having replicated the finding that children performed just as well on no-article trials as on grammatical-article trials (G&M, 1993; McNamara et al., 1998), we focus our remaining analyses on comparisons between the grammatical- and nonce-article conditions.

A key question in Experiment 1 was how children younger and older than those observed by Gerken and Macintosh (1993) would respond to anomalous articles in an online word recognition task. Although there was no significant age $\times$ determiner interaction in the analyses of accuracy or RT, we conducted planned comparisons between the grammatical- and nonce-article conditions within each age group to explore age differences on both measures in greater detail. As shown in Figure 2, children were significantly less accurate on nonce-article than grammatical-article trials at both 18 months (nonce: $M = .58$, $SD = .14$, grammatical: $M = .65$, $SD = .11$, $t(33) = 2.29$, $p < .05$, and 24 months (nonce: $M = .66$, $SD = .15$, grammatical: $M = .71$, $SD = .13$, $t(33) = 2.06$, $p = .05$). However, for 36-month-olds there was no difference between these conditions. In the analysis of mean RT as well, the children in the youngest group were significantly slower on nonce-article trials than on grammatical-article trials. As shown in Figure 3, 18-month-olds were 88 ms slower on average to identify a familiar noun when it was preceded by a nonce ($M = 932$ ms, $SD = 223$) rather than a grammatical article ($M = 844$ ms, $SD = 204$), $t(33) = 2.18$, $p < .05$, although 24- and 36-month-olds were equally fast to identify the target word across conditions.

Shift-backs were analyzed in a 3 (age) $\times$ 2 (determiner type) mixed ANOVA. Children shifted equally often in the nonce-article ($M = 1.09$, $SD = .44$) and grammatical-article conditions ($M = 1.05$, $SD = .45$), $F(1, 94) = .40$, $p > .71$. Thus the idea that nonce-articles caused retroactive confusion was not supported by our data. A reliable main effect of age showed that 18-month-olds shifted back and forth slightly more overall ($M = 1.2$, $SD = .51$) than did 24- ($M = .97$, $SD = .37$) and 36-month-olds ($M = 1.0$, $SD = .39$), $F(2, 93) = 4.36$, $p < .02$.

Analyses by determiner use in speech production—We next examined whether susceptibility to disruption by a nonce article varied as a function of children's level of linguistic proficiency, in particular their production of articles in spontaneous speech.

Children were grouped according to whether or not they produced determiners, as reported by their parents. Note that children who reportedly produced determiners in their own speech were on average older than children who were reported as not yet producing determiners. If children using determiners are more able to ignore an anomalous article than children not yet producing determiners, we would expect to find an interaction between determiner production and determiner type. Accuracy scores were compared in a 2 (determiner type: grammatical, nonce) $\times$ 2 (determiner production: producers, non-producers) mixed ANOVA. Both main effects were significant: Accuracy was higher overall on grammatical- ($M = .71$, $SD = .13$) than nonce-article trials ($M = .67$, $SD = .16$), $F(1,96) = 7.10$, $p < .009$, and those children who produced determiners in their own speech were more accurate overall ($M = .76$, $SD = .13$) than those who did not ($M = .64$, $SD = .13$), $F(1, 96) = 27.38$, $p < .0001$. As predicted, the interaction between determiner type and determiner production was also significant, $F(1,96) = 4.25$, $p < .05$. As shown in Figure 4, those children who did not yet produce determiners were significantly less accurate on nonce-article ($M = .61$, $SD = .14$) than on grammatical-article trials ($M = .67$, $SD = .12$), $t(52) = 3.45$, $p < .001$, while those who did produce determiners were equally accurate on nonce- ($M = .75$, $SD = .15$) and grammatical-article trials ($M = .76$, $SD = .12$).

The parallel analysis of mean RTs also yielded a significant main effect of determiner production, reflecting faster RTs by determiner-producers ($M = 758$ ms, $SD = 190$) than determiner-non-producers ($M = 871$ ms, $SD = 230$), $F(1,88) = 9.29$, $p < .003$. However, although mean RT was slower in the nonce-article ($M = 835$ ms, $SD = 202$) than the grammatical-article condition ($M = 806$ ms, $SD = 236$), neither the main effect of determiner type nor the interaction with determiner production was reliable. Once again, our accuracy measure revealed a difference in processing efficiency that was not evident in the RT data, presumably because the accuracy scores included all the data from every child in the study while the RT analyses were limited to only a subset of trials from a subset of the children.

Discussion

The goal of Experiment 1 was to replicate and extend previous research exploring how comprehension is affected when very young language learners encounter a nonce article before a familiar object name. Using online measures to capture the child's immediate response from target noun onset on each trial, we found that children were significantly less accurate overall on nonce-article trials than on grammatical-article trials. However, it was only the younger and linguistically less advanced children who showed disruption when encountering an anomalous article; older and linguistically more advanced children were able to "listen through" a nonce article preceding a familiar word. This pattern of developmental differences is consistent with findings from studies using offline measures by Gerken & McIntosh (1993), who found that comprehension by 2-year-olds was disrupted on nonce-article trials as compared to grammatical-article trials, and by McNamara, et al. (1998), who found that comprehension by 4-year-olds in a similar task was *not* disrupted on nonce-article trials.

In Experiment 1, reaction time measures were weaker than accuracy measures for several reasons, all related to the fact that RT means were of necessity based on far fewer trials than means for accuracy scores (see Fernald et al., 2001). An inherent constraint in a 4-min online experiment with infants is that the overall number of trials must be low, a particular liability when using a within-subject design with three conditions, and children were not always attentive on all 8 of the critical trials per condition. Although accuracy could in principle be calculated on every trial in each condition for every child, speed of processing could only be measured on those trials when the child happened to start out on the distracter picture and shift to the target. Since children started out on the distracter only about half the time, the number of trials yielding RTs for each child varied from 1 to 6 per condition, but

for 40% of the participants the mean RT was based on only one or two trials in one or more conditions. Mean RTs that are based on so few trials, in some cases on single responses that were unusually slow or fast, inevitably increased the variability among the means across conditions and reduced the likelihood that significant differences would emerge. Thus it was not surprising that the measures of children's accuracy were more robust and revealing than the measures of response speed. Despite these limitations, the RT differences were consistent in direction with the group differences in accuracy.

In Experiment 1 we also replicated previous findings that children regardless of age had no difficulty identifying a familiar word when the determiner was missing altogether (G&M, 1993; McNamara et al., 1998). In our data, planned comparisons showed no differences in performance at any age between no-article and grammatical-article trials. This result is unsurprising, given that children frequently hear grammatical noun phrases with no determiner, as in *Where's Mary?* and *I like cookies*. However, a possible alternative explanation for this negative finding is that children simply did not perceive no-article sentences with animate nouns (e.g., *Where's doggy?*) as ungrammatical because such count nouns can also be used as proper names. Since half of the target nouns in Experiment 1 were animate, this could perhaps explain why children performed equally well on no-article and grammatical-article trials.⁴ To explore this possibility, we conducted separate analyses of accuracy and RT measures on trials with animate and inanimate target words in the no-article condition. However, we found no differences at any age related to the animacy of the target noun, suggesting that this factor could not account for the finding here and in previous studies that young children's comprehension is not adversely affected when a familiar noun is presented in a sentence without an article.

On trials when a nonce article was present, the apparent indifference of older, linguistically more advanced children to violations of the familiar article/noun sequence could at first seem puzzling. One might expect that children who produce determiners in their own speech would be relatively *more* vulnerable to disruption when encountering an uninterpretable functor-like syllable in the speech they hear, as compared to children who have not yet begun to use determiners as grammatical elements in multiword utterances. However, the negative findings with linguistically more advanced children can also be interpreted as a sign of more advanced competence in speech processing, rather than as a paradoxical "failure to notice" the ungrammatical word. Because the target words in Experiment 1 were all familiar and always occurred in final position in repetitive and prosodically similar sentence frames, the processing task was highly predictable. In this situation, the prenominal functor words were redundant and uninformative. Efficiency in this case could take the form of judiciously ignoring an ambiguous but uninformative nonce syllable in the process of rapidly identifying the subsequent object name that is the focus of the sentence. The linguistically less advanced children may not have been able to take advantage of this redundancy because the target words were less well known to them, and because they did not yet appreciate articles as grammatical elements separable from the noun that follows. This leads to the prediction that if children who were experienced with determiners were tested on newly learned words, rather than on familiar words they have known for half their lifetime, they too would find it more difficult to identify a target word preceded by a nonce article than a grammatical article.

EXPERIMENT 2

Experiment 2 explored the possibility that the linguistically more experienced children in Experiment 1 could afford to "listen through" the anomalous articles preceding well known

⁴Thanks to an anonymous reviewer for suggesting this interpretation and analysis.

object names because of their familiarity with the target words and the high level of predictability overall in the testing situation. We hypothesized that if confronted with a less predictable processing task, even children more advanced in production of grammatical morphemes would experience disruption when encountering anomalous articles, as did the younger and less experienced language learners in the first experiment. To make the task more challenging in Experiment 2, we first taught two novel words to 34-month-olds, who were all producing determiners in their own speech. Given that lexical unfamiliarity is known to disrupt children's production of articles and other functor words (e.g., Boyle & Gerken, 1997), would the relative unfamiliarity of a newly learned object name influence online processing of articles as well? Children were tested on the two novel object names and two familiar object names, each presented with grammatical and nonce articles. We expected that 34-month-olds would easily identify both familiar and newly learned target words preceded by grammatical articles, although newly learned words would be identified less reliably overall. We also expected that a familiar word following a nonce determiner would not be problematic, consistent with the performance of the older, linguistically more advanced children in Experiment 1. The key prediction in Experiment 2 was that when children encountered a newly learned target word preceded by a nonce article, their processing efficiency would be disrupted. Thus we expected to find an interaction between word familiarity and determiner type.

Method

Participants—Participants were 30 34-month-olds ($M = 2;10.7$, range: 2;8.9 to 2;11.18). Five additional children were excluded from the final sample because of fussiness. All children produced determiners in their own speech, according to parental report.

Interactive Word Teaching Procedure—The goal of this initial offline task was to introduce two novel words *dax* and *kreeb* to the child prior to testing in the online procedure. By teaching these novel words in a face-to-face situation, the experimenter could adjust the timing and dynamics of the session to maximize the child's attentiveness and ensure that both words were reliably recognized before proceeding to online testing.

Visual stimuli: A picture book with 17 pages was used to present pictures of two unfamiliar objects corresponding to the novel words *dax* and *kreeb*, as well as five familiar filler objects. The novel objects were a multicolored pinwheel and a yellow figurine, matched for size and salience. Teaching stimuli consisted of four pages depicting one novel object, alternated with four pages depicting the other one. Testing stimuli consisted of four pages on which both novel objects were presented, with side of presentation counterbalanced. Teaching and testing pages were interspersed with five filler pages.

Speech stimuli: In the interactive procedure the novel words were always spoken in sentence-final position in the same two carrier frames (*This is a dax*, *Where's a dax?*). During teaching, both novel words were always preceded by the article *a* and never by *the*; during subsequent online testing, these novel words were always preceded by *the* in the grammatical article condition (*Where's the dax?*). Thus previous experience with a particular article/noun sequence during teaching was not confounded with grammaticality of the article during testing, and the child heard both the grammatical sequence *the dax* and the ungrammatical sequence *po dax* or *loo dax* for the first time in the online test procedure.

Procedure: The child sat at a table beside the experimenter. Labels assigned to the novel objects were counterbalanced across participants. During teaching, the experimenter labeled the novel object twice on each of the eight teaching pages. Then the experimenter showed the four test pages on which both novel objects were depicted, asking *Where's a dax?* on

two pages and *Where's a kreeb?* on two, in alternating order. Children had to correctly identify the referents for both novel words twice each to demonstrate that they could map the sound-forms to the appropriate pictures. Otherwise the teaching phase was extended until the child met this criterion before progressing to the online task.

Looking-while-listening Procedure

Speech stimuli: Target words consisted of *car* and *shoe*, along with the two novel words, *dax* and *kreeb*, all target words recorded in sentences with both grammatical and nonce articles. The nonce articles were two of the CV syllables used in Experiment 1, /pɛ/ and /lu/. The carrier frames *Where's _* and *Which is _* were used for both target words in both determiner conditions. Each child was tested on six sentences in each of four conditions, resulting in 24 experimental trials:

1. Familiar word with grammatical article (e.g., *Where's the shoe/car?*)
2. Familiar word with nonce article (e.g., *Which is loo shoe/car?*)
3. Novel word with grammatical article (e.g., *Which is the dax/kreeb?*)
4. Novel word with nonce article (e.g., *Where's po dax/kreeb?*)

The familiar and novel target words were each presented three times with a grammatical article and three times with a nonce article. For half the children, *loo* was paired with familiar words and *po* with novel words; for half the other pairing was used. Twelve filler sentences were also included.

Speech stimuli were recorded, selected, edited, and cross-spliced as described in Experiment 1. Carrier frames were matched in duration ($M = 526$ ms; range = 515 to 569 ms). Grammatical and nonce articles were also matched in duration across tokens: grammatical articles ($M = 166$ ms; range = 163 to 169 ms); nonce articles ($M = 165$ ms; range = 165 to 167 ms). Mean duration of the novel target words was 495 ms; mean duration of the familiar target words was 499 ms. Mean duration of the stimulus sentences was 1180 ms (range: 1159 to 1194).

Visual stimuli: Visual stimuli were digitized images corresponding to *car* and *shoe*, and to the two novel words *dax* and *kreeb*. Six different tokens of each familiar object were used. For the novel words the same images of the novel objects shown in the picture book were used, with backgrounds modified to increase variation.

Apparatus and procedure: Same as in Experiment 1

Coding and dependent measures: Same as in Experiment 1. Inter-observer reliability was 99% for both measures of reliability, as described in Experiment 1.

Results

Figure 5 shows the time course of orienting by 34-month-olds to the correct picture in the four conditions. Although 3-year-olds who produced determiners in Experiment 1 identified familiar target words with equal facility following grammatical and nonce articles (see Figure 1C), Figure 5 suggests that the children in Experiment 2 responded differentially to familiar and novel object names, and that nonce articles had a disruptive effect in both conditions.

Mean accuracy scores were compared in a 2 (word familiarity: familiar, novel) $\times$ 2 (determiner type: grammatical, nonce) repeated measures ANOVA. Both main effects were highly significant. Children were more accurate overall in identifying well known target

words ($M = .82$, $SD = .14$) than newly learned target words ($M = .69$, $SD = .19$), $F(1, 29) = 14.76$, $p < .0006$. They were also more accurate overall in identifying target words preceded by a grammatical article ($M = .79$, $SD = .18$), than by a nonce article, ($M = .72$, $SD = .17$), $F(1, 29) = 8.92$, $p < .006$. Contrary to our prediction, there was no significant interaction of word familiarity and determiner type.

As in Experiment 1, RT data were only available for a subset of the participants on a subset of trials. Thirteen children with missing data in one or more conditions were excluded from analysis. As with accuracy, the main effects of word familiarity and determiner type on reaction time were both significant in Experiment 2. Children were faster in identifying familiar target words ($M = 651$ ms, $SD = 199$) than novel target words ($M = 881$ ms, $SD = 353$), $F(1, 16) = 14.05$, $p < .002$. They were also faster in identifying target words preceded by grammatical articles ($M = 668$ ms, $SD = 268$) than by nonce articles, ($M = 865$ ms, $SD = 315$), $F(1, 16) = 12.23$, $p < .003$. The interaction of word familiarity and determiner type was not significant.

Shift-backs—Shift-backs were analyzed in a 2 (word familiarity) $\times$ 2 (determiner type) repeated measures ANOVA. There were no significant main effects; however, the word familiarity $\times$ determiner type interaction was reliable, $F(1, 29) = 5.49$, $p < .03$. Follow-up tests showed that with familiar target words, children shifted equally often on nonce- ($M = .97$, $SD = .42$) and grammatical- ($M = .99$, $SD = .33$) article trials, $p < .87$, *n.s.* However, with novel words, children shifted significantly more often on nonce-article trials ($M = 1.16$, $SD = .47$) than on grammatical-article trials ($M = .96$, $SD = .44$), $t(29) = 2.55$, $p < .02$. This suggests that children were confused on those trials with the highest level of uncertainty, i.e., when hearing a nonce article in combination with a relatively unfamiliar object name.

Discussion

Experiment 2 yielded three main findings: First, 34-month-olds responded more rapidly and reliably to familiar object names than to newly learned words. Their ability to identify novel words correctly in both offline and online procedures showed they had made the appropriate mapping between the new words and their assigned referents. Even so, they were significantly faster and more accurate in response to target words they had known for longer, consistent with findings from other online studies in which children were tested on recently learned words (e.g., Zangl & Fernald, 2005). Second, although linguistically more experienced children were not disrupted by ungrammatical articles before familiar object names in Experiment 1, the same nonce articles were problematic in the context of an object name that was less familiar. The 34-month-olds in Experiment 2 were significantly slower and less accurate in identifying a newly learned target word when it followed a nonce article than a grammatical article. Thus, although children can ignore an anomalous article when interpreting a sentence in a highly redundant context, the same anomalous determiner is disruptive when they are listening for a less familiar word and uncertainty is higher, even for linguistically more experienced children. The third and unexpected finding was that the nonce articles in Experiment 2 also caused disruption when they preceded familiar words, contrary to findings with the linguistically advanced children in Experiment 1. Although participants in the second experiment were two months younger than the oldest children in Experiment 1, both groups of participants produced determiners in their own speech. It seems likely that the use of novel target words and the high proportion of challenging trial types overall made the children in Experiment 2 wary and prone to false alarms, an hypothesis to which we return in the next section.

GENERAL DISCUSSION

In two experiments with 18- to 36-month-old children who varied in whether or not they produced determiners in their own speech, we used online methods to investigate developmental changes in efficiency of processing articles in continuous speech. Four major findings emerged: First, 18-month-olds were slower and less accurate in recognizing a familiar noun when it was preceded by a nonce article than when it was preceded by a grammatical article. By measuring the time course of speech processing, we showed that the nonce article was problematic immediately, disrupting processing by interfering with word recognition within milliseconds of hearing the target noun. The second major finding was that the extent of disruption caused by a nonce article decreased with age: 24-month-olds responded equally fast but still less accurately on nonce-article trials, and the 36-month-olds in Experiment 1 were not affected at all, identifying a familiar target word just as quickly and reliably in grammatical- and nonce-article sentences. The third finding was that children's ability to resist disruption when encountering a nonce article before a familiar object name was related to their own use of determiners in speech production. Children not yet able to produce determiners were adversely affected by nonce articles before familiar object names, while children who used determiners in their own utterances were not. Finally, although older and more linguistically advanced children could "listen through" an anomalous article in conjunction with a familiar noun, their ability to process articles was still fragile with novel nouns that were less familiar. The 34-month-olds in Experiment 2 experienced much more difficulty identifying a newly learned object name when it was preceded by a nonce article as compared to a grammatical article. Moreover, in this less predictable context the presence of a nonce article disrupted word recognition even for familiar object names.

Insights Gained from Using Online Measures of Speech Processing

By using online rather than offline measures to assess the efficiency of children's comprehension, we extended the results of Gerken and McIntosh (1993) in several respects. Although the nonce articles used here could have been more difficult for young children to detect than the CVC syllable used by G&M, we replicated two main findings of their original study: first, that language novices were less accurate in identifying a familiar word preceded by a nonce article than by a grammatical article, and second, that they were not adversely affected when the article was missing altogether. By monitoring children's eye movements as the target word was spoken rather than requesting a pointing response at the end of the sentence, we showed not only that the 18-month-olds were less accurate overall on trials with nonce articles, but also that they were slower to identify the target word even when they did respond correctly. An important question left open by earlier research was whether the anomalous article interfered immediately with access to the target word, or whether the child identified the word correctly but then became confused as to how to respond to the ungrammatical sentence. In two later studies, Gerken and colleagues provided indirect support for the "early-disruption" hypothesis that a nonce functor interfered immediately with lexical access, at least for typically developing two-year-olds (Carter & Gerken, 1996; McNamara, et al., 1998). Our findings offer more direct evidence in favor of early-disruption as an explanation for the reduced accuracy of 18-month-olds when they encountered a nonce functor. As shown in Figure 1A, differences in performance on nonce-article trials began to emerge as soon as the target word was spoken. If children had experienced difficulty in establishing reference only *after* successfully identifying the target word on nonce-article trials, we would expect a different pattern—a comparable rise in target picture fixation on both grammatical- and nonce-article trials, followed by divergence of the curves caused by subsequent shifts away from the target. Instead we found that 18-month-olds were thrown off by the nonce article almost immediately, making more incorrect

choices overall and responding more slowly even when they did identify the target word correctly. Children showed no greater tendency to shift back and forth between pictures on nonce-article than on grammatical-article trials, as they would do if confusion set in after hearing the entire sentence. This pattern of results suggests that it was the form of the article that influenced how infants processed the target word as the noun phrase unfolded over time.

What Factors Account for Increased Flexibility in Children's Speech Processing?

Although 18-month-olds typically do not yet produce articles, by three years of age most children have learned to use a range of determiners across different contexts. Why then in Experiment 1 did a nonce word in place of the article make it harder for younger and less linguistically experienced children to recognize the familiar object name that followed, yet cause no problem for the presumably more discerning older children? By 14 months infants can distinguish correctly spoken words from mispronunciations, suggesting that lexical representations of familiar words are phonetically well specified at this age (Swingley & Aslin, 2002; Fennell & Werker, 2003). However, speech processing efficiency is still considerably less efficient at 18 months than six months later (Fernald et al., 1998; 2006) and younger infants may have more difficulty dealing with noisy elements such as the nonce syllables used here. Moreover, recent research showed that speech degradation had a more adverse effect on word recognition by linguistically less advanced children in this age range, demonstrating that the extent of interference by pervasive noise in the speech signal varied with the level of lexical development (Zangl, Klarman, Thal, Fernald, & Bates, 2005).

But even when speech is clear and the contextual perturbation is local, as in the present study, language novices may be more vulnerable to disruption in the article/noun sequence than linguistically more experienced children. Although adults recognize that *a* and *the* can both be used as articles, children just beginning to produce one-word utterances may not at first appreciate that such brief, unstressed functor words are actually distinct from the word that follows, much less that *a* and *the* belong to the same grammatical category. And even when children start to produce articles in appropriate contexts at the end of the second year, they are likely to use *a* with some nouns and *the* with others but not to use both with the same noun (Pine & Martindale, 1996). It is only around the age of three that most children have learned to produce determiners correctly wherever called for (Abu-Akel, et al., 2004; Kemp, et al., 2005; Pine & Lieven, 1997). This pattern of gradual item-based learning of article/noun sequences over the second and third years suggests that children start as conservative learners, initially focused on regularities in the surface forms of particular articles co-occurring with particular nouns (Tomasello, 2003). In previous encounters with object names like *ball* and *doggy*, these nouns were almost always preceded directly by determiners such as *the*, *a*, *this*, or *that*. Thus *the ball*, *the doggy*, etc. are highly familiar as two-word sequences, while *po ball* and *loo doggy* are not. An early reliance on such lexically-specific co-occurrences in the speech stream may lead very young language learners to take a more bottom-up, form-based approach to segmenting and parsing the input. This could explain why the younger and linguistically less experienced children in Experiment 1 were quite efficient in recognizing familiar nouns preceded by *the*, but had difficulty when the same object name was heard in a novel article-noun combination. It is interesting to note that older children with SLI continue to rely on surface form when they encounter ungrammatical determiners, further evidence that this is a less mature processing strategy (McNamara, et al., 1998).

By three years, children's ability to use articles across different contexts suggests that they have learned to appreciate the functions of determiners at a more abstract level. That is, they demonstrate awareness that determiners mark the beginning of a noun phrase that they are obligatory in certain syntactic contexts and incorrect in others, and that their selection depends on pragmatic factors related to establishing reference. If children have an abstract

category of determiners as a grammatical form class by this age, this could be one factor in explaining why older and linguistically more experienced children in Experiment 1 were able to identify familiar object words rapidly and reliably even when preceded by functor-like nonce words. As children gain experience with the whole class of determiners that can introduce a noun phrase, they may develop greater tolerance of phonetic variability in functor words preceding object names. More experience with language would also increase tolerance for acoustic variability due to speaking rate and emotional tone as well as differences among speakers. All of these factors could make the older and linguistically more advanced child less susceptible to disruption by an anomalous determiner preceding a familiar noun. As long as the word in the determiner slot is short and unstressed, phonological characteristics common to functor words across languages, it may be more or less acceptable as an article to a child who has had extensive experience with determiners (Shi, et al., 1998). With increasing linguistic experience, the child may also notice that variability among such words in prenominal position is often irrelevant to interpreting the noun that follows in order to establish reference. Thus a nonce article would be easy to ignore, at least in the highly predictable sentence processing context of Experiment 1.

Predictability and Children's Online Processing

Although in Experiment 1 the more advanced language learners were not disrupted by a nonce syllable co-occurring with a familiar word, we expected that in a more challenging task the same nonce syllable would be disruptive even for children experienced with determiners. This hypothesis was motivated by extensive research showing that the predictability of the language processing task affects performance by adults and children. Some of the earliest experimental studies of spoken word recognition explored how the predictability of the linguistic context affects the intelligibility of the target word (e.g., Miller, Heise, & Lichten, 1951; Lieberman, 1963). For example, Warren's (1970) classic study revealed that adults failed to detect a mispronounced syllable in a linguistically coherent context, yet noticed the same syllable when the context was less predictable. Although syntactic coherence has a major influence on the efficiency of speech processing by adults, lexical familiarity also plays an important role. In one recent study, adults were pretrained on sentences composed of either familiar English words or nonce words, and then were asked to identify these words in noise-vocoded speech, a form of acoustically distorted speech that preserves temporal but not spectral information (Davis, Johnsruide, Hervais-Adelman, Taylor & McGettigan, 2005). Accuracy increased over time, but only for listeners trained on sentences containing English words, indicating that lexical familiarity was critical in enabling adults to learn to process such degraded speech more efficiently. For young language learners as well, lexical familiarity affects performance on linguistic tasks, although most developmental studies have used outcome measures related to speech production rather than speech processing. Boyle and Gerken (1997) found that 2-year-olds were more likely to omit articles from sentences containing novel rather than familiar nouns and verbs. Kemp, et al. (2005) also found that children were more likely to omit articles before novel words learned only recently than articles before well known words, further evidence that lexical familiarity affects performance in early speech production.

To explore whether lexical familiarity influences speech processing as well as speech production in children just beginning to use determiners, we tested 34-month-olds in Experiment 2 comparable to the more advanced children in Experiment 1. After learning two novel words, both preceded by the article *a* during training, children were tested on these novel words preceded either by *the* or by the nonce article *po* or *loo*. Thus during teaching the indefinite article was used in both conditions to indicate that the novel word was a count noun, and then during testing the child heard the new word paired with either the definite article or a nonce determiner. As predicted, children were less proficient overall

in recognizing the relatively unfamiliar, newly learned target words than the highly familiar words, and they performed worst on trials with a newly learned word preceded by a nonce article. However, they were significantly more accurate in identifying these newly learned words preceded by *the* than by a nonce article, although prior to testing they had never heard the novel words combined with the article *the*. Thus it could not be children's form-based familiarity with a particular article/noun sequence that led to better performance on *the dax* trials than on *loo dax* trials, but rather their recognition of *the dax* as a more appropriate sequence given knowledge of the kinds of words that can come before object names in English. These results extend the findings of Experiment 1 by showing that children find it easier to process a familiar grammatical article than a nonce article even in the context of a novel noun, and that the lexical familiarity of the noun also affects children's success in processing articles in fluent speech.

An unexpected finding in Experiment 2 was that nonce articles were not only disruptive to more experienced language learners on novel-word trials but also on familiar-word trials, contrary to the findings with more linguistically advanced children in Experiment 1. Why would a well known object name in an anomalous noun phrase such as *po shoe* be more difficult to process in the context of one stimulus set than another? While most studies of speech processing have focused on elements *within* the sentence that influence efficiency in word recognition, the extent of predictability *across* the stimulus set can also affect adults' performance. For example, in studies of semantic priming with adults, a common finding is that the strength of priming increases with the proportion of semantically related words used as stimuli (e.g., Den Heyer, 1985). This "proportion effect" is interpreted as evidence that a high proportion of valid primes increases participants' expectations that prime words have predictive validity. If very few of the primes are related, participants learn quickly that they are not useful. This kind of explanation could be relevant to the situation encountered by the more advanced language learners in our two experiments, since the test stimuli in Experiment 2 were much less predictable overall than those in Experiment 1. The children in Experiment 2 were tested on novel words on 12 of 24 trials, and half the time these newly learned words were preceded by a nonce article. In addition to the lexical unfamiliarity of the target words, variability in stimulus type was greater across the stimulus set as a whole. Children not only heard novel target words with both grammatical and nonce articles, but even on control trials with familiar target words, a nonce article preceded the object name half the time. Thus, on 75% of the trials in Experiment 2, something was potentially confusing, while in Experiment 1 nonce articles occurred on only a third of the trials and all the target words were familiar. Moreover, on half the trials with articles in Experiment 1, the familiar article *the* provided a valid cue that a well known object name noun would follow, while in Experiment 2 the predictive validity was lower. Thus, children may have been more susceptible to disruption by anomalous articles on familiar-word trials in Experiment 2 because of the higher level of unpredictability and the reduction in cue validity across the stimulus set. Other research has also shown that children's performance on the same stimuli varies as a function of the composition of the overall stimulus set (Gerken, Murphy, & Aslin, 1995; Swingle & Aslin, 2007).

Another possible explanation for the apparent discrepancy between 3-year-olds' efficiency in processing familiar words across the two experiments is that Experiment 2 had a teaching phase in which children heard object names in a *single* article context (e.g., *a dax*, *a ball*) preceding the online testing. In contrast, Experiment 1 had no teaching phase prior to the online task, and thus children came to the online testing 'unbiased', i.e., without any expectation that an object name would occur in a particular context. It could be that hearing object names in only one article context in the teaching phase induced some form of exemplar-based lexical priming which biased children to include the article in the representation that was assessed in the online testing.⁵ Although this assumption seems

plausible, given that children this age do show priming in some determiner contexts (Kemp et al., 2005), it seems unlikely as an explanation for the present results. On the exemplar-based lexical priming account, performance on familiar words should have been affected on grammatical and nonce-article trials, and this was not the case. Three-year-olds were more efficient processing familiar words preceded by *the* than *po*, although both article contexts were equally new to them in the testing phase. Moreover, children's performance on the grammatical trials in Experiment 2 was comparable to that in Experiment 1. Thus, we consider it unlikely that the teaching phase of Experiment 2 accounts for the discrepancy between the results in the familiar word condition across Experiments 1 & 2.

Given the variability among the stimuli in Experiment 2, there might be concern about the generalizability of these results to children's language processing in more natural situations. However, the pattern of results in the second experiment was so orderly overall that it cannot be explained as an artifact of unusual task demands. On familiar-word trials with grammatical articles, i.e. the kinds of sentences heard by children in everyday speech, the more advanced learners achieved equally high levels of accuracy in Experiments 1 and 2. The effects of increased unpredictability in Experiment 2 were only evident on those trials in which the article, the target word, or both were novel. As predicted, children performed best on trials with familiar object names preceded by grammatical articles, just as in Experiment 1, and worst on trials that combined novel object names with novel articles. On trials with only one novel element, either a newly learned noun or a nonce article, performance fell in between. Thus success in sentence processing by linguistically more advanced children was enhanced both by lexical familiarity and by the predictability of particular sequences of words within the noun phrase. On familiar-word trials, given the simple visual and auditory context of our testing situation, the article was actually irrelevant to establishing reference. Although the youngest infants did not yet appreciate the redundancy of the article in this context, the older and more experienced children could afford to listen through the uninformative prenominal word even when it was a nonce syllable.

To say that 3-year-olds were sufficiently flexible in online processing to be able to listen through an anomalous nonce syllable in place of the article is not to say that the nonce syllable went unnoticed. Although in the testing context used here it was not important to attend to the prenominal word to identify the correct referent, in other contexts attention to the determiner is essential. Two- and 3-year-olds are already adept at using determiners as morphosyntactic cues to noun class (e.g., Katz, Baker, & McNamara, 1974). For example, all nouns in Spanish are either masculine or feminine in grammatical gender, and Spanish-learning children take advantage of gender-marking on the article to identify the following noun more rapidly (Lew-Williams & Fernald, 2007). In English as well, determiners carry important information. When asked *Where's the dax?* English-learning 2- and 3-year-olds interpret the novel word as a count noun (Gelman & Taylor, 1984), but when asked *Where's dax?* they favor a proper name interpretation (Jaswal & Markman, 2001). Zangl and Fernald (2006) replicated these findings in a recent study using online methods. When 3-year-olds were taught that *dax* referred to a novel inanimate object (as in Experiment 2 in the present research), they interpreted the newly learned word as a count noun in response to both *Where's the dax?* and *Where's po dax?* However, in a second condition in which no lexical training occurred, the situation was fully ambiguous. As children looked at two unfamiliar objects, one animate (a troll doll) and one inanimate (a constructed object matched in visual complexity), they heard a completely novel word, presented once with a grammatical determiner and once with a nonce determiner. In response to *Where's po meek?* in this situation, children preferred the animate over the inanimate object, consistent with a proper-

⁵Thanks to an anonymous reviewer for suggesting this interpretation.

name interpretation. When asked *Where's the meek?* they looked equally to both objects, an appropriate response given that an animate object can be labeled either with a count noun (*dog*) or with a proper name (*Fido*). This testing situation differed from those in the present research in that the child did not have a name for either object. Moreover, the visual array afforded a proper-name attribution, but only in the context of a linguistic stimulus consistent with that interpretation. These findings illuminated children's increasing flexibility in online comprehension from another angle: 3-year-olds were able to listen through a nonce syllable such as *po* in a highly redundant context in which it was plausible to interpret *po* as a "noisy" but uninformative article, consistent with a count-noun interpretation. However, the nonce syllable did not go unnoticed, because in a different context with a salient animate object as a potential referent, children clearly attended to the nonce syllable, interpreting *po* as the first syllable of a proper name.

Conclusions

Learning what to attend to and what it is possible to ignore is essential in developing efficiency in processing spoken language. This may be particularly relevant when it comes to function words, which occur in syntactically highly constrained positions and do not convey meaning in the same way that content words do. Highly frequent function words are typically much less salient than content words as acoustic elements in the speech stream, and speakers reduce the salience of function words even further when the linguistic context is more predictable (Bell et al., 2003). Skilled listeners can compensate for this reduction in phonological specificity by relying on top-down linguistic knowledge to make sense of the utterance, as long as other features of the sentence context are sufficiently predictable. Our findings provide new evidence for the gradual emergence of this kind of flexibility in speech processing over the first three years of life. The linguistic novice, just beginning to use words in combination, relies on surface regularities and lexical familiarity in the speech input, and so finds it more difficult to interpret a familiar object name when it co-occurs with an unfamiliar functor-like nonce word. The older and linguistically more advanced child has had more extensive experience with determiners as a class of words that occur in highly constrained contexts with varying pronunciation. Increasingly, acoustic variability within this class of words can be ignored as irrelevant as long as the discourse context is predictable. More advanced language learners are also more efficient in anticipating the focus of the spoken sentence, in this case the upcoming object label, and thus can ignore a "noisy" syllable in place of the article when it is unlikely to modulate the meaning of the focused word. However, when the discourse context supports an interpretation in which the same anomalous syllable is potentially meaningful, two- and three-year olds make immediate and efficient use of this information (Zangl & Fernald, 2006). One way to characterize the developmental gains in processing skill revealed here is in terms of children's growing appreciation of determiners as an abstract grammatical category. However, the finding that with increasing linguistic experience, children's attention to the phonological appropriateness of the article varies with the familiarity of the word and the redundancy of the linguistic context highlights other important implications of this developmental trajectory as well: that children become gradually more proficient in interpreting spoken language as they learn to integrate probabilistic cues that enable them to predict what is coming next in speech.

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FIGURE 1.

Time course of looking to target picture in three determiner conditions in Experiment 1: (A) 18-month-olds; (B) 24-month-olds; (C) 36-month-olds. Curves depict changes in proportion of looking over time to picture named by familiar target word preceded by grammatical article (squares), no article (circles), and nonce article (triangles). The vertical dashed line indicates the offset of the target word.

FIGURE 2.

Mean proportion of time looking to target picture in grammatical (grey) and nonce (white) determiner conditions in Experiment 1 as a function of age for 18-, 24-, and 36-month-olds.

FIGURE 3.

Mean reaction times (ms) to orient to the target picture from the onset of the target word in grammatical (grey) and nonce (white) determiner conditions in Experiment 1 as a function of age for 18-, 24-, and 36-month-olds.

FIGURE 4.

Mean proportion of time looking to target picture in grammatical (grey) and nonce determiner (white) conditions in Experiment 1 as a function of determiner production for children not yet producing determiners in their own speech vs. children reportedly producing determiners.

FIGURE 5.

Time course of looking to target picture by 34-month-olds in Experiment 2 in response to familiar object words (*car*, *shoe*) and newly learned novel object words (*dax*, *kreeb*) preceded by grammatical and nonce articles. Curves depict changes in proportion of looking over time to correct picture in four conditions: familiar word/ grammatical article (filled squares); familiar word/ nonce article (unfilled squares); novel word/ grammatical article (filled triangles); novel word/ nonce article/ (unfilled triangles).