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Little Words, Big Impact: Determiners Begin to Bootstrap Reference by 12 Months

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ABSTRACT

We tested 12- and 18-month-old English-learning infants on a preferential-look task which contrasted grammatically correct sentences using the determiner “the” vs. three ungrammatical conditions in which “the” was substituted by another English function word, a nonsense word, or omitted. Our design involved strict controls on phonetic composition of function words and co-articulation effects in the stimuli tested, which were absent in previous studies. The results show an overall significant effect of Function Word (FW), with no significant interaction effects between the two age groups. Overall, infants oriented faster to a target image and had more correct first looks at target following grammatical sentences. Tests within age groups show a significant effect of FW in 18-month-olds for both latency and correct first look, documenting a linguistic sensitivity, which persists over our new acoustic variables. In the 12-month-olds there was a significant effect of FW on first look, although no significant effect of FW for latency appeared. However, pairwise comparisons showed a significant difference between grammatical and ungrammatical FWs in latency even at this age. These findings suggest that some prototypical form of sensitivity to determiners in sentence processing and its use in computing noun reference exists already during early developmental stages surrounding the child’s first words. We speculate on potential explanations for developmental changes between 12 and 18 months.

Researchers continue to ask: What is the nature of children’s representation of functional elements such as determiners (e.g., the, a) at early stages of language development, and how may it change over time?

A wide range of behavioral research has now documented the emergence of fine-detailed phonetic representations for functional words and morphemes (FWs) throughout children’s first year of life (e.g., Demuth, 1992, 1994; Gerken, Remez, & Landau, 1990; Katz, Baker, & MacNamara, 1974; Maratsos, 1982; Petretic & Tweney, 1977; Shipley, Smith, & Gleitman, 1969). More recently, an array of cross-linguistic studies has shown that infants encode FWs phonetically from about 6 months of age. In fact, already before their first birthday, infants have been found to: (i) discriminate FWs from content words, demonstrated in infants even a few days old (e.g., Shi, Werker, & Morgan, 1999); (ii) segment FWs from continuous speech (Höhle & Weissenborn, 2003; Shafer, Shucard, Shucard, & Gerken, 1998; Shi & Gauthier, 2005); (iii) discriminate and prefer well-formed FWs over nonsense FWs (Hallé, Durand, & de Boysson-Bardies, 2008; Shady, 1996; Shi, Cutler, Werker, & Cruickshank, 2006; Shi, Werker, & Cutler, 2006); (iv) use FWs to segment novel noun forms (Shi & Lepage, 2008); and (v) detect specific co-occurrence patterns between bare roots and their inflected variants (Marquis & Shi, 2012).
This line of evidence has often figured in ongoing debates regarding children’s early representation and processing of functional categories (FCs). These grammatical categories, which are reflected in language by FWs, serve as phrasal heads that carry a critical role in establishing the structural skeleton of sentences and enable essential syntactic operations (e.g., movement) in language (Abney, 1987; Chomsky, 1995; Pollock, 1989). However, some researchers have argued that early discriminative effects of FWs in perception reflect infants’ excellence in acoustic processing, but no abstract grammatical knowledge. Rather, the infant changes qualitatively at some later point in time, transforming from item-based (mainly phonetic) processes in infancy to grammatical, category-based incorporation of FWs in sentence processing. This non-continuous developmental trajectory has been attributed to infants’ early ability to discern various acoustic and distributional characteristics that FWs often share. For example, FWs are the most frequent items in every human language; typically have a monosyllabic lexical structure; and appear in fixed peripheral phrasal positions (Aslin, 1999; Morgan, 1986; Seidl & Johnson, 2006). Only later, it is argued, do children make a qualitative shift to a point where abstract grammatical representations of FCs become available; and this is only after the child has gained sufficient exposure to content word categories (e.g., Pine & Lieven, 1997; Tomasello, 2000a, 2000b; Zangl & Fernald, 2007).

Other scholars hypothesize that infants’ discriminatory behaviors in response to particular FWs are guided by an inherent sensitivity to linguistic properties of the FCs to which these FWs belong, and thus reveal more than perceptual processing of acoustic elements of language (e.g., Lust, 2006; Shi, 2014; Valian, 2008, 2009; Yang, 2013). Focusing on determiners, Valian, Solt, and Stewart (2008) systematically analyzed thousands of natural speech utterances from 21 children aged 1.10–2.8 years and argued that “even at the onset of combinatorial speech, children have abstract functional categories” (773). An array of studies with L1 learners of Dutch, English, French, and German using various methods and measures yielded evidence that young children not only detect FWs in the linguistic input, but also consult various aspects of FWs and the syntactic contexts in which they appear in sentences already during their second year of life (Bernal, Dehaene-Lambertz, Millotte, & Christophe, 2010; Bernal, Lidz, Millotte, & Christophe, 2007; Bobb & Mani, 2013; Cauvet et al., 2014; Cyr & Shi, 2013; Golinkoff, Hirsh-Pasek, & Schweigkuth, 2001; Höhle, Schmitz, Santelmann, & Weissenborn, 2006; Kedar, Casasola, & Lust, 2006; Robertson, Shi, & Melançon, 2012; Santelmann & Jusczyk, 1998; Shady & Gerken, 1999; Van Heugten & Shi, 2009).

Some evidence for abstract linguistic knowledge has been obtained with even younger infants close to the 12-month age range (Höhle, Weissenborn, Kiefer, Schulz, & Schmitz, 2004; Kedar, 2009; Shady, 1996; Shi & Melançon, 2010; Soderstrom, White, Conwell, & Morgan, 2007; Zhang, Shi, & Li, 2015). For example, Höhle et al. (2004) found that 14-month-old German-learners grasp the category information related to a novel (nonsense) word based on the particular type of FW preceding it (e.g., a determiner, as in ein glamm); and then also generalize this information to other syntactic contexts in which the novel word appears (e.g., with other German determiners; das glamm). That is, they use the determiner to syntactically categorize adjacent novel words. Similarly, Shi and Melançon (2010) have found that French-learning 14-month-olds can detect and use a set of distinct determiners preceding novel words to categorize these words as nouns. However, these results are somewhat inconsistent. While both studies have found that 14-month-olds use determiners to categorize novel words into nouns (but not 12–13 month-olds; Höhle et al., 2004), no such evidence was found in terms of verb categorization (i.e., subject pronouns were not perceived as a common syntactic class). In a recent study, Zhang et al. (2015) report a significant discrimination of grammatical vs. ungrammatical test trials based on functors in Mandarin-Chinese-Learning 12-month-olds, however only in later stages of the test phase (Block 2).

In sum, it has been demonstrated that very young infants distinguish FWs based on their distinct phonetic forms in the linguistic input; and also consult this phonetic discrimination in online sentence processing. A central question in our view is how early during development do children provide evidence that they are beginning to use FWs to link form and meaning? Specifically, with regard to determiners: How early do children begin to link their linguistic discrimination of this
grammatical category (DET) to (semantic) visual reference? We pursue this question beginning at the age of 12 months, approximately the age of first productive word usage (e.g., Fenson et al., 1994) and some early aspects of word comprehension (e.g., Swingley, 2005; Thierry, Vihman, & Roberts, 2003). We find the 12-month marker to be particularly intriguing because several broader developmental changes have been documented at this stage in the integration and reorganization of infants’ phonological, prosodic, lexical, and semantic representations (e.g., DePaolis, Vihman, & Keren-Portnoy, 2014; Kuhl, Ramírez, Bosseler, Lin, & Imada, 2014; Lust, 2006; Pruden, Hirsh-Pasek, Golinkoff, & Hennon, 2006; Werker & Yeung, 2005; Yeung, Chen, & Werker, 2014).

If FWs begin to carry a role in the integration of grammatical form and reference already around 12 months of age, as they are a few months later, infants may be able to utilize this sensitivity to facilitate the acquisition and integration of different linguistic domains from very early stages of lexical and grammatical acquisition. Indeed, early access to FWs has often been assumed to be necessary for bootstrapping various aspects of language learning (Christophe, Millotte, Bernal, & Lidz, 2008; Gerken, 2007; Shi, 2007); and to assist infants in realizing certain formal aspects in their language (Gervain, Nespor, Mazuka, Horie, & Mehler, 2008; Valian, 2008). For example, preverbal infants have been found to rely on well-formed FWs—but not on nonsense functors—to segment adjacent nouns (11 months: Hallé et al., 2008; 8 months: Shi & Lepage, 2008). Gervain et al. (2008) demonstrated that 8-month-old learners of Italian and Japanese consult the frequency and location patterns of function and content elements in these two languages to determine the linear word order representation for their native language.

**This study**

Our study follows the design of Kedar et al. (2006), in which 18- and 24-month-old English-learners tested on an intermodal preferential looking procedure (IPLP; Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987) demonstrated different looking patterns to a target image in response to grammatical sentences vs. ungrammatical sentences in which a single FW was manipulated (e.g., “Can you see the cup?” vs. “Can you see *and ball?”). These findings were replicated in a follow-up study with sixteen 12-month-old infants (Kedar, 2009). These two studies replicated the findings of a seminal study by Gerken and McIntosh (1993) in which two-year-olds were tested on a picture-pointing task with a similar set of sentences.

However, the results attained in these studies allow some alternative explanations. Most critically, the comparison between the grammatical determiner “the” vs. the nonsense word “el” and the ungrammatical English FW “*and*” is confounded by the variation in consonant-initial (CV) syllable structure. Studies have documented infants’ difficulty in segmenting onsetless vs. onset words (Nazzi, Dilley, Jusczyk, Shattuck-Hufnagel, & Jusczyk, 2005; Seidl & Johnson, 2008); that is, vowel-initial (VC) as opposed to consonant-initial (CV) syllables and words, respectively. Thus, infants could have discriminated these two types of forms on this phonetic basis, potentially preferring the consonant-initial “the” because of depression in processing of vowel-initial words in utterance medial position.

In addition, co-articulation factors could have contributed to the results. Kedar and colleagues created their test sentences by splicing the prototype for the carrier phrase “can you see”—as well as the prototype nouns following the FW (e.g., phone, dog)—from grammatical sentences. Infants have been shown to be sensitive to subtle co-articulation cues, and to use such cues for word segmentation (e.g., Curtin, Mintz, & Byrd, 2001; Johnson & Jusczyk, 2001). Hence, the auditory stimuli could lead to subtle, yet detectable, acoustic differences between the test sentences, with only grammatical sentences featuring an agreement in co-articulation between the carrier phrase (can you see) and the FW (the), and between the FW and the following noun, whereas the deviant co-articulatory nature of the ungrammatical sentences may have disrupted infants’ processing of those sentences.
These acoustic differences would not in themselves explain early use of FWs to determine reference. However, such uncontrolled acoustic variables, either individually or in combination, would allow both linguistic and acoustic factors as potential contributions to infants’ greater success at the correct determiner form in our task. To explore this issue further, we created new auditory stimuli that isolate grammatical from acoustic/phonetic properties in ways that allow an assessment of their potential contributions to the observed results.

Our study shares key features with Kedar et al. (2006) and Kedar (2009), yet modifies their experimental designs to control several acoustic factors as potential explanations of the results. Similar to Kedar et al., our design contrasts grammatical sentences in which the English determiner “the” precedes a monosyllabic singular count noun (e.g., “Can you see the dog?”) with three types of similar yet ungrammatical conditions, in which “the” is substituted with an English FW (by), which is itself well-formed, but non-grammatical in the sentence context in which it appears; substituted with a nonsense word (bo); or dropped (“null”). To test infants in a manner consistent with previous studies, we again used the IPLP, which has been successfully applied to test various aspects of language acquisition during children’s first three years of life (Golinkoff, Ma, Song, & Hirsh-Pasek, 2013). We also endorsed the methodological modifications in Kedar (2009), taking into account infants’ more limited attentional resources as well as their partial lexical familiarity at 12 months. Lexical unfamiliarity has been shown to affect infants’ performance on both production and perception of sentences (e.g., Boyle & Gerken, 1997; Zangl & Fernald, 2007). Thus, we reduced the size of the original set of test nouns used in Kedar et al. based on the lexical norms of the MacArthur-Bates Communicative Development Inventory (MBCDI; Dale & Fenson, 1996) at 16 months—to 8 nouns, which all have relatively high familiarity rates at 12 months according to the MBCDI for monosyllabic, singular count nouns. Moreover, we replicated the noun familiarization phase in Kedar (2009) to increase the likelihood that infants would be familiar with the appropriate linguistic label for each of the images. This could then focus infants on the actual task rather than on deciphering what a certain noun refers to, as in a word-learning task. Lastly, following Kedar (2009), the overall time during which the target and distractor images were simultaneously presented was reduced from 6 sec to 4 sec, to decrease the likelihood that infants lose interest in the task.

Our study addresses the two potentially confounding acoustic variables mentioned above. First, in order to eliminate an acoustic-based account whereby the results could alternatively be explained based on infants’ bias in favor of the grammatical condition (“the”, a CV syllable) vs. the vowel-initial ungrammatical FWs (“and”, “el”), we maintained “the” as the FW in the grammatical condition, but used consonant-initial FWs in the two ungrammatical FW-substitution conditions as well (by, bo).

Second, to avoid the possibility that distinction between grammatical and ungrammatical sentences could potentially be explained in terms of distinct coarticulation cues, we changed the manner in which the auditory stimuli were prepared and edited. In this study, the words comprising the final (edited) test sentences were all spliced from ungrammatical sentences (in grammatical sentences, the FW prototype for “the” was spliced from a grammatical sentence, but the carrier phrase and the noun were taken from the ungrammatical sentences). Our manipulation produced identical coarticulation cues across grammatical and non-grammatical forms.

In addition, the fact that the preposition “by” served as the English FW which is not grammatical in the test sentences (in contrast to “was” and “and” previously), allows us to test whether young language learners are able to detect yet another fine-detailed distinction between two legitimate English function words, each fulfilling a different grammatical function and belonging to a different functional category in language. Note that combinations of [by+Noun] may and do occur in English (e.g., “He is old enough to have a drink by cup”; “Those who arrive by car can park here”; “Some athletes are getting paid by shoe companies”). Furthermore, “Can you see by” is also a legitimate sequence in English (e.g., “Can you see by the smile on my face?”; “O! Say can you see by the dawn’s early light...”). Hence, if infants in both age groups (12 and 18 months) discriminate “the” from the
Two dependent variables that capture different aspects of infants’ looking response to the linguistic manipulation were assessed to test this hypothesis. Based on Kedar et al. (2006) and Kedar (2009), we predicted latency to target (duration of time passed during test trials from the moment the pair of images first appears to infants’ initial fixation to target) to be the most sensitive measure because it is continuous (time-based) and tracks infants’ very first looking response to the linguistic manipulation. Specifically, in comparison to the ungrammatical conditions, infants presented with grammatical sentences were predicted to orient faster to the target image. Second, a dichotomous, first look to target measure, was based on whether infants correctly oriented to the target image on their first look. We predicted the highest proportion of correct first looks to appear following grammatical sentences with the well-formed determiner.

Method

Participants

All infants who took part in the study were reported by their parents to be full-term and healthy, with no history of any auditory or visual impairment, and hearing only English regularly. The majority of infants at each age were Caucasian. For the 18-month-old group, 16 infants (9 females; 7 males) were recruited. The mean age (months; days) was 18;05 (SD = 7.66 days) ranging between 538 and 564 days. Fourteen additional infants were not included in the final sample. Eleven infants expressed fussiness during most or all of the testing session (i.e., when crying or disinterest in the stimuli across several consecutive trials made it impossible to complete the session), while in three other cases a technical problem in running the experiment occurred. For the 12-month group, 18 infants (eight females, 10 males) were recruited. The mean age (months; days) was 12;01 (SD = 9.36 days), ranging between 349 and 380 days. Fourteen additional infants were not included due to fussiness during most or all of the test session (n = 8), a technical problem (n = 5), or a child raised in a bilingual environment (n = 1).

Stimuli

Eight images with the highest familiarity proportion for their corresponding nouns among 12-month-old English-learners according to the MBCDI were chosen as the visual stimuli. Four pairs with approximately the same noun-familiarity proportion in each pair were created (See Table 1). Accordingly, the auditory stimuli consisted of 32 sentences based on all possible combinations of the

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Table 1. (i) Mean percentage of infant familiarity at 12 months with the test nouns according to the Macarthur-Bates Communicative Development Inventory (MBCDI); and (ii) Mean percentage of infant estimated familiarity with these nouns according to the parents of the infants tested in this study (only “Yes” responses were counted as indicating infant familiarity with the nouns).

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>“Yes”</td>
<td>“No”</td>
<td>“Not Sure”</td>
</tr>
<tr>
<td>1</td>
<td>Phone</td>
<td>58</td>
<td>91.7</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>Cup</td>
<td>55.7</td>
<td>91.7</td>
<td>8.3</td>
</tr>
<tr>
<td>2</td>
<td>Ball</td>
<td>79.5</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Book</td>
<td>68.2</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Cat</td>
<td>45.3</td>
<td>75</td>
<td>16.7</td>
</tr>
<tr>
<td></td>
<td>Dog</td>
<td>69.3</td>
<td>83.3</td>
<td>16.7</td>
</tr>
<tr>
<td>4</td>
<td>Car</td>
<td>53.4</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Shoe</td>
<td>62.5</td>
<td>75</td>
<td>25</td>
</tr>
</tbody>
</table>
eight nouns and the four exemplars of FW used in this study (See Table 2). This set of 32 sentences was digitally recorded and edited in several stages to create test sentences that would be distinguished only by their grammatical structure rather than by their phonological or prosodic characteristics. First, a female, native-English speaker produced several versions of each of the 32 sentences in moderate speed so that each word would be clearly separated from the others. Next, to avoid a possible co-articulatory bias in favor of the grammatical sentences over the ungrammatical sentences, two adult native-English speaking judges who were blind to the experiment’s goals listened carefully and separately several times to the set of 24 ungrammatical sentences, and then marked the best exemplar of the sequence “can you see” in terms of vividness, naturalness and clarity. The specific “can you see” sequence which got the highest combined score was then spliced in as a prototype for all of the edited sentences that were eventually used in the test trials (grammatical and ungrammatical alike). Similarly, the clearest exemplar of each noun was chosen from the set of ungrammatical sentences and then spliced in as a prototype in all sentences in which it appeared (grammatical and ungrammatical alike). Finally, for each type of FW, the best exemplar agreed on by the two judges was spliced in to create a set of eight sentences for that condition. The edited test sentences lasted about 2 s (mean: 2071.9 msec; SD = 218.65 msec; range = 1620–2498 msec), depending on the FW used and mainly on the noun (mean length of noun = 457.1 msec; SD = 94.8 msec; range: 300–592 msec). In “null” sentences, in which “the” was omitted, a very brief gap of silence was inserted between the verb “see” and the following noun in order to keep the sentence at the 2 sec timeframe. Lastly, four (other) adult native English speakers (2 females, 2 males. Mean age = 21:08 yy:mm) were presented (separately) with each of the 32 edited test sentences and were asked to judge whether each sentence sounded natural and had normal prosodic characteristics for an interrogative sentence in English. All sentences were indeed confirmed as natural sounding by each judge.

**Table 2.** Lists of sentences.

<table>
<thead>
<tr>
<th>Test Trial</th>
<th>Pair</th>
<th>Target</th>
<th>Side of Target</th>
<th>List 1</th>
<th>List 2</th>
<th>List 3</th>
<th>List 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cup-Phone</td>
<td>Phone</td>
<td>Left</td>
<td>the phone?</td>
<td>by phone?</td>
<td>bo phone?</td>
<td>_ phone?</td>
</tr>
<tr>
<td>2</td>
<td>Car-Shoe</td>
<td>Car</td>
<td>Left</td>
<td>by car?</td>
<td>bo car?</td>
<td>_ car?</td>
<td>the car?</td>
</tr>
<tr>
<td>3</td>
<td>Ball-Book</td>
<td>Ball</td>
<td>Right</td>
<td>_ ball?</td>
<td>the ball?</td>
<td>by ball?</td>
<td>bo ball?</td>
</tr>
<tr>
<td>4</td>
<td>Cat-Dog</td>
<td>Dog</td>
<td>Right</td>
<td>the dog?</td>
<td>by dog?</td>
<td>bo dog?</td>
<td>_ dog?</td>
</tr>
<tr>
<td>5</td>
<td>Cup-Phone</td>
<td>Cup</td>
<td>Left</td>
<td>_ cup?</td>
<td>the cup?</td>
<td>by cup?</td>
<td>bo cup?</td>
</tr>
<tr>
<td>6</td>
<td>Car-Shoe</td>
<td>Shoe</td>
<td>Right</td>
<td>bo shoe?</td>
<td>_ shoe?</td>
<td>the shoe?</td>
<td>by shoe?</td>
</tr>
<tr>
<td>8</td>
<td>Cat-Dog</td>
<td>Cat</td>
<td>Right</td>
<td>bo cat?</td>
<td>_ cat?</td>
<td>the cat?</td>
<td>by cat?</td>
</tr>
</tbody>
</table>

*Note. All sentences began with the sequence “Can you see...”.*

**Apparatus**

Adjacent experimental and control rooms were used. In the experimental room, three 20-in color monitors were placed on a table approximately 76 cm from the floor. Infants were seated on their parent’s lap approximately 127 cm from the monitors. Low lighting and a black wooden frame surrounding the monitors were used to focus infants’ attention on the monitors. An opening in the frame enabled a camcorder lens to be focused on the infant’s face. This camcorder was linked to a monitor in the control room, allowing the experimenter to observe the infant during the test session. All test sessions were video-recorded to allow offline frame-by-frame coding of each infant’s looking behavior using the SuperCoder software (Hollich, 2003). The Habit X software (Cohen, Atkinson, & Chaput, 2004) was used for controlling the order and the timing of the audio-visual presentation throughout the test session.
**Procedure**

All parents were blind to the experimental design and were only given a general description of the procedure. Following a 15-min play session, during which the infant was accustomed to the lab setting and to the experimenters, and parental consent was obtained, the child and the parent entered the experimental room, where the actual test occurred. Parents wore darkened sunglasses to avoid affecting their infant's looking patterns. Infants were seated on their parent’s lap so that their eyes directly faced the center of three TV monitors. Before the experimenter left the experimental room, parents were reminded to remain neutral and to avoid talking to their infant during the entire test session.

Infants were randomly assigned to one of four lists of sentences. In each list there were eight sentences, with two sentences corresponding to each of the test conditions (i.e., *the*, *by*, *bo*, *null*). Order of the different four conditions was quasi-randomized across lists (see Table 2). Each infant was presented with eight consecutive test cycles in which a familiarization trial was followed by a baseline trial and then a test trial. Each Familiarization-Baseline-Test cycle lasted about 40 sec, with the entire testing session lasting around 6 min. As illustrated in Table 3, a flashing, chiming, green circle serving as an attention-getter appeared on the center monitor prior to beginning each test cycle. During familiarization, each image was presented separately three times on the center monitor, accompanied by its linguistic label, for 3 sec (e.g., “ball”, “book”, “ball”, “book”, “ball”, “book”). Thus, each image was presented for a total duration of 9 s. During the subsequent baseline and test trials, the same two images were presented simultaneously on the left and right monitors. During baseline trials, infants first heard the recorded voice encourage their looking to the images (“Look! Look at these!” or “Look! Look at that!” counterbalanced across all baseline trials) and then viewed the pair of images for 4 sec. After 2 sec, infants heard “wow!” to maintain their attention. During test trials, a test sentence was heard, followed by a presentation of the same pair of images for 4 sec, with each of the images placed in the same positions as in the preceding baseline trial (i.e., the left and right monitors). A 270 msec pause occurred in baseline and test trials from sentence end to first appearance of the images on the monitors. Following the first four test sessions (*Cup-Phone, Car-Shoe, Ball-Book, Cat-Dog*), infants viewed the same pairs again in the same order. Each image in a pair served as the target image in one test trial and as the distractor in the other test trial in which that pair of images appeared. To control for side preference, the side in which the target image appeared was quasi-randomized across test sessions in the following order: *left, left, right, right, left, right, left, and right*. Therefore, infants who were in fact orienting to the target images based on the linguistic input would often have to shift their gaze from one side to the other across the different image pairs. To avoid a recency bias during the baseline and test trials (based on whether the last image seen during familiarization was the target image or the distractor)—the order in which the images were presented during familiarization was quasi-randomized as well. Images seen last during familiarization trials were presented in the following order: *target, distractor, distractor, target, distractor, target, target, and distractor*. Therefore, there was no direct relation between which image appeared last during familiarization and which image served as target during the subsequent baseline and test trials. After the experiment had ended, parents were asked to estimate their infant’s familiarity with each of the eight test nouns. Parents also reported whether their child produced any of the test nouns and/or other words, including FWs.

**Coding**

The videotaped test sessions were coded off-line using the SuperCoder software (Hollich, 2003). This program creates a 30-frame-per-second transcript of the session and allows a frame-by-frame analysis of the infants’ looking behavior. Specifically, in the familiarization trials, infants’ looking behavior was coded during the 3 sec presentation of each image (x 3). During baseline and test trials, infants’ looking behavior was coded from first appearance of the two images until these images disappeared. From a total of 272 test cells, there were 36 test cells from 16 different infants that were not included in the analyses due to fussiness or non-attentiveness during a baseline trial and/or the subsequent test trial. An experimenter who was blind to the experimental conditions coded all test
sessions. A second experimenter coded nine of the 34 test sessions (five 18-month-olds, four 12-month-olds). The average correlation between the two observers indicated high inter-observer reliability: 0.94 (range: 0.90–0.99).

### Results

#### Parental reports

As Table 1 demonstrates, the parental reports estimating their 18-month-old infants’ familiarity with the nouns used in the study indicated high familiarity levels: Mean = 86.46%; SD = 10.85%; Range = 75–100%. As expected, the parental reports for the 12-month-olds showed relatively lower and more variable familiarity levels: Mean = 66.55%; SD = 19.4%; Range = 30.77–92.31%. In terms of speech...
production, the 18-month-olds were reported to produce 47.73% of the test nouns on average (SD = 19.28%; Range = 18.18–81.82%). In regards to those infants’ general productive vocabulary, the mean number of words reported to be produced by the 18-month-old infants was 20, none of which were reported to be FWs (only one infant was reported to occasionally use a single FW, “that”). In the 12-month age group, parents reported their infants to produce only 22.32% of the test nouns on average (SD = 20.36%; Range = 0.00–50.00%). The 12-month-old infants’ average productive vocabulary was 5 according to the parental reports, none of which were FWs (as with the older age group, there was one instance of an infant who was reported to occasionally use “that”).

**Attention ratio**

Two attention ratio measures were used to estimate infants’ interest in the visual stimuli during the test sessions. In familiarization trials, we calculated the time an infant looked towards the presented image, divided by the overall 9 sec during which this image appeared on the center monitor (i.e., 3 sec × 3). The mean overall attention ratio in both age groups suggests that infants were in fact attentive enough to form an association between the noun labels and their visual representations during familiarization: In the 18-months group, the mean overall attention ratio was .81 (SD = .20); while in the 12-months group it was .69 (SD = .22). Similarly, in the baseline trials and the test trials, the attention ratio measure was based on the time an infant looked towards either image in a pair, divided by the overall 4 sec during which both images appeared on the left and right monitors. The results in both age groups indicate that the infants were in fact interested in the visual display: In the 18-months age group, the overall mean attention ratio during baseline trials was .74 (SD = .18), and .64 during test trials (SD = .16). In the 12-months age group, the overall mean attention ratio during baseline trials was .76 (SD = .19), and .62 (SD = .21) during test trials.

**Statistical analyses**

The statistical analyses were completed using the IBM SPSS Statistics 20.0 software. In the statistical analyses mentioned henceforth, there was no significant interaction involving Sex nor was there a main effect for Sex. For this reason, Sex was omitted as a variable in subsequent analyses.

**Latency to target**

To test for the effects of Function Word and Age on Latency to Target, we ran a linear mixed-effects model (LMM) which enables to fit linear mixed-effects models to data sampled from normal distributions. Specifically, we used the Restricted Maximum Likelihood (REML) method, which yields asymptotically efficient parameter estimators for unbalanced data, as was the case in our experiment (i.e., the two age groups were unequal in size, 16 vs. 18 infants; and some of the cells were missing, that is, we did not get two measurements for each infant on each FW type). Our LMM analysis included participant (child) as the random effect (random subject intercepts); and the Satterthwaite approximation method for DF calculation. Following a log transformation (justified by a residual analysis), the analysis yielded a statistically significant effect for Function Word, F (3,204) = 5.80, p = .001, overall. As Figure 1 demonstrates, infants in both age groups responded similarly to the visual stimuli and oriented to the target image faster following grammatical sentences. No interaction between Function Word and Age, F (3,204) = .29, ns; or a main effect for Age, F (1,32) = 1.06, ns., were found. Pairwise comparisons among the four FW conditions yielded significant overall differences between the grammatical condition and each of the ungrammatical conditions: THE vs. BY, t (204) = 2.00, p < .05; THE vs. BO, t (205) = 3.70, p < .001; THE vs. NULL, t (202) = 3.46, p = .001. No significant differences among the ungrammatical conditions were found.
Although we found no interaction with Age, we analyzed each age group separately. In the 18-months age group, a statistically significant effect for Function Word, $F(3,204) = 3.83, p = .01$ was found. A priori, theoretically motivated pairwise comparisons, revealed significant differences between THE vs. BO, $t(206) = 3.09, p < .01$, and between THE vs. NULL, $t(201) = 2.75, p < .01$. The comparison between THE vs. BY approached significance, $t(204) = 1.86, p = .06$. No significant differences among the ungrammatical conditions were found.

However, for infants of 12 months, there was no significant effect for Function Word, $F(3,204) = 2.01, ns$. Nonetheless, specific pairwise comparisons were significant: THE vs. BO, $t(204) = 2.11, p < .05$; THE vs. NULL, $t(203) = 2.12, p < .05$. The comparison between THE vs. BY was not significant, $t(204) = .94, ns$. No significant differences among the ungrammatical conditions were found.

**First look to target**

As Figure 2 demonstrates, in both age groups, the grammatical condition initiated more correct first looks in comparison to each of the ungrammatical conditions. Due to the binary nature of the outcome (YES/NO), we used a Generalized Estimating Equation (GEE) logistic regression analysis (Liang & Zeger, 1986). We fitted the logistic regression in the framework of the GEE to account for the personal differences among the infants. Testing for the effects of Function Word and Age on correct first look, the GEE analysis yielded only a significant effect of Function Word, $\chi^2(3) = 20.14, p < .001$ overall, hence replicating the Latency findings. No interaction between Function Word and Age, $\chi^2(3) = .14, ns$; or a main effect for Age, $\chi^2(1) = .04, ns$—were found. Pairwise comparisons among the four FW conditions yielded significant differences between THE vs. BO, $\chi^2(1) = 9.52, p < .01$; THE vs. NULL, $\chi^2(1) = 18.70, p < .001$; and between BY vs. NULL, $\chi^2(1) = 7.11, p < .01$. The comparison between THE vs. BY was not significant, $\chi^2(1) = .79, ns$. 

![Figure 1. Infants’ mean latency (±Std error) in seconds to the target image during test trials, as a function of Function Word (the/by/bo/null).](image-url)
Again, although no interaction with Age was found, we analyzed the two age groups separately. In the 18-months age group, a significant effect for Function Word, $x^2 (3) = 8.62, p < .05$, was found. Pairwise comparisons revealed significant differences between THE vs. BO, $x^2 (1) = 6.48, p < .05$, and between THE vs. NULL, $x^2 (1) = 7.32, p < .01$. The comparison between THE vs. BY was not significant, $x^2 (1) = .75, ns$. No significant differences among the ungrammatical conditions were found.

Within 12 months alone, a significant effect of Function Word, $x^2 (3) = 14.42, p < .01$, was found. Pairwise comparisons revealed a significant difference between THE vs. NULL, $x^2 (1) = 12.99, p < .001$; and between BY vs. NULL, $x^2 (1) = 5.49, p < .05$. The comparison between THE vs. BO approached significance, $x^2 (1) = 3.74, p = .055$. The comparison between THE vs. BY was not significant, $x^2 (1) = .16, ns$.

**Discussion**

This study replicates earlier findings with 18- and 24-month-old infants, confirming that previous results were not solely due to acoustic properties of the stimuli, which were controlled in our new design. In this way, they suggest that some linguistic competence guides early discrimination and use of determiners in addition to acoustic sensitivities that the child may have. Recall that in this study we only used consonant-initial (CV) FWs in both the grammatical and ungrammatical conditions alike (the/by/bo). Thus, unlike Kedar et al. (2006) and Kedar (2009), in which the results could be aided by the fact that only the ungrammatical FWs (and, el) were vowel-initial (and consequently harder to process than the consonant-initial “the”), the set of FWs used in our study rules out such an acoustic-based explanation for our findings. Nonetheless, infants distinguished grammatical sentences from ungrammatical ones. These results may be interpreted as suggesting that even at these early ages, some form of prototypical grammatical sensitivity to particular FWs may exist independent of their acoustic variation; and that the developing processes of (content) word learning, sentence processing, and determination of the semantic function of noun reference—are mediated to some degree by children’s integration of FWs such as determiners in their representation of language.
In addition, the current findings reveal continuity in infants’ developing language competence, already at 12 months of age and long before FWs are integrated in the child’s productive speech overtly, to distinguish sentences that only differ in a single English FW. The overall failure of our analyses to find a significant effect of age in the combined analysis of the 12 and 18 months groups across measures (neither Latency to Target nor First Look); the clear pattern similarities across age groups (seen in Figures 1 and 2); and the significant within-age pairwise comparisons between grammatical and ungrammatical function words—all point to a basic continuity in these data.

At the same time, our results also point to developmental processes that occur during the 12–18 months period. In general, these findings and those reported by Kedar et al. (2006) illustrate that some gradual development is taking place from 12–24 months of age in terms of attentiveness, lexical familiarity, and speed of processing. For example, the latency analyses in both studies suggest that younger infants take more time to orient to target across all four conditions; and that for younger infants, lexical familiarity and productive vocabulary are limited in comparison to older age groups. More specifically, at 12 months of age, a significant effect of FW appears only in first look, not in latency to target. This result may be a function of infants’ overall slower latencies, combined with the fact that we lowered our stimulus presentation time to 4 sec to accommodate for the reduced attention span at 12 months. This may have counteracted a known increased slowness in processing at this age (e.g., Vihman, Nakai, DePaolis, & Hallé, 2004; Zhang et al., 2015). The emerging literature on FW processing around 12 months of age points to infant sensitivity to subtle differences in task, which relate to basic differences in processing timing. Thus, one challenge in this line of inquiry now is to calibrate comparisons between specific age group around the 1-year marker with regard to known variations in latency across development.

Furthermore, the pairwise comparisons showed that infants’ response to “by” did not seem to be consistently distinct from “the” (compared to the clear distinction between “the” vs. “bo” and “null”). While in the Latency to Target analysis the comparison between “the” and “by” was statistically significant, the within group latency analyses failed to yield a significant effect on this contrast. In terms of correct first look, the same comparison did not reach significance in any of the analyses performed. Interestingly, the comparison between “by” and “null” was significant in the general First Look analysis as well as the 12-month first look analysis.

One possible explanation for this set of results is based on integration between two different computational mechanisms. First, infants’ well-documented excellence in acoustic processing as well as their sensitivity to transitional probabilities and co-occurrence patterns in their linguistic input as they compute sentences (e.g., Cartwright & Brent, 1997; Chemla, Mintz, Bernal, & Christophe, 2009; Gerken, Wilson, & Lewis, 2005; Lany & Gomez, 2008; Mintz, 2006; Mintz, Newport, & Bever, 2002; Safran, 2001). In particular, this study—as well as previous findings (see the “null” condition results in Kedar et al., 2006; Kedar, 2009; Petretic & Tweney, 1977; and Shipley et al., 1969)—demonstrates that English-learning infants notice the omission of pre-nominal functors. That is, infants seem to develop a general expectation for an article to precede a (count) noun; an expectation that is presumably based on the transitional probability of such co-occurrences in spoken English.

Second, it has been shown that frequent FWs become part of the child’s lexicon earlier than less-frequent FWs, and play a more robust role in aiding infants in extracting novel lexical items from continuous speech input. For example, Shi and Lepage (2008) found that the high-frequency French functors “des” and “mes”—as opposed to a nonsense FW, “kes”; or an infrequent FW, “vos”—facilitated the phonetic segmentation of subsequent nouns by French-learning 8-month-olds (see also Shi et al., 2006a, 2006b). Such bias towards higher-frequency and simple-structured lexical items, as found in word segmentation studies, also seems to be the case in infants’ incorporation of FWs in sentence processing and word categorization (e.g., Höhle et al., 2004). Thus, it is possible that by 12 months, English-learning infants may have already formed a form-meaning competence to Noun Phrases that contain the high-frequency FW “the”, but may not have had sufficient exposure to less-frequent Noun Phrases with “by” in order to integrate them in deriving the meaning and visual reference of a Noun Phrase. Furthermore, note that “by”, as opposed to “the”, has a wide
Looking patterns in English may suggest a period of the looking differences across the 1981 perception. There is an associated discrimination between English FWs “the” vs. “by” relative to other contrasts such as “bo” (presumably recognized as “Not a FW”) in English may suggest a period of lexical learning.

In general, our findings stand in contrast to a long-held view according to which infants and even much older children initially attend only to content words in the speech stream (e.g., Bowerman, 1973; Grimshaw, 1981; Pine & Lieven, 1997; Radford, 1997; Schlesinger, 1971; Tomasello, 2000a)—and correspond with the large emerging literature that has challenged this earlier view on two main grounds. First, although FWs are often absent from children’s first utterances in English-speaking communities, the timing and manner in which earliest productions of FWs occur cross-linguistically vary considerably. Second, in perception, infants have been found to possess fine-detailed phonological representations for both function and content words already during the first year of life; and to incorporate FWs in sentence computation during their second year. The current findings point to developmental continuity in this respect between 12 and 18 months of age (and beyond: See Gerken & McIntosh, 1993; Kedar et al., 2006).

More broadly, our results strengthen the view according to which infants’ early language processing—much like adult speakers—is facilitated when function and content words are structurally combined at the phrasal and sentential levels, rather than operating on a telegraphic, single-word basis (e.g., Aslin, Woodward, La Mendola, & Bever, 1996; Fernald & Hurtado, 2006; Gomez & LaKusta, 2004; Hallé et al., 2008; Höhle et al., 2004, 2006; Kedar et al., 2006; Soderstrom et al., 2007). Note that although the infants we tested could have simply ignored the pre-nominal FW and instead located the visual target by attending to its corresponding noun—the looking differences across the experimental conditions indicate that the infants consulted particular FWs which appeared (or were absent, “null”) in each of the test sentences. This was the case even though they could form a word-object association based solely on lexical labels (e.g., “book”). Instead, the infants’ looking patterns suggest that they had processed the grammatical structure of the test sentences, in particular, the Determiner Phrase (DP)—and then used this information to facilitate the establishment of noun reference in their visual environment.

Children’s knowledge or processing of FC structure is clearly not fully available at 12 months. For example, Shady (1996) found that infants’ sensitivity to the exact sentential location and order in which certain FWs may appear develops between 10 and 16 months of age. Another line of work has shown progression during the first 2 years in category-based abstraction of FWs (e.g., Gerken et al., 2005; Gomez & Lakusta, 2004). As noted above, other studies have revealed developmental processes in the differentiation of FCs (e.g., Höhle et al., 2004; Shi & Melançon, 2010). In fact, it may take children years to fully acquire their language-specific functional lexicon and link it to semantics as well as to syntax (e.g., the relatively late discrimination between definite vs. indefinite articles by English-learners; Foley, Lust, Battin, Koehne, & White, 2000; Schaffer & Matthewson, 2005).

Still, our findings suggest that infants consulted a specific determiner (word; “the”) representing the Determiner (category; DET) in determining reference; that this process is not solely determined by acoustic factors such as coarticulation effects or phonetic property of syllable onset; and that it

In fact, studies using various research strategies have provided evidence that children’s omission of FWs—when present—is predominantly based on limitations in speech processing, planning and production, which are phonological in nature (e.g., Boyle & Gerken, 1997; de Lange et al., 2009; Demuth, 1992; Dye, 2011; Gerken, 1994; Gerken et al., 1990; Kirk & Seidl, 2004; Lust, 2006; Valian et al., 2008).

Hence, it is unlikely that the obtained responses were based on infants’ rote memorization of holistic combinations of “the” and each of the test nouns (e.g., “thetable”, “thebook”).
appears to play a continuous role in this way by about 12 months and beyond. That is, our results do not provide empirical evidence for a qualitative change in infants’ incorporation of FWs in sentence processing. Our findings thus cohere with the hypothesis that FWs and their corresponding FCs provide the child with a syntactic skeleton that serves a crucial role in parsing the speech stream into its phrasal constituents, as well as in linking between syntax and semantics—in line with the Syntactic Bootstrapping Hypothesis (Fisher, Gleitman, & Gleitman, 1991; Gerken, 2007; Hirsh-Pasek & Golinkoff, 1996; Landau & Gleitman, 1985).

In sum, this study suggests that language development between 12 and 18 months lies in the child’s integration of parallel acoustic, distributional and grammatical knowledge. We have found that 12-month-olds store familiar words and their referents in such a way that involves computation of and referral to particular FWs. This means that at least some FWs must enter into the linguistic data that the infant is accessing and storing. In particular, the DP seems to link syntax and semantics, even before well-developed combinatorial language production. Although there is much about acquisition of FWs such as determiners yet to be developed subsequently (both semantically and grammatically), this early ability appears to be foundational.

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