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### Function Words Constrain On-Line Recognition of Verbs and Nouns in French 18-Month-Olds

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# Function Words Constrain On-Line Recognition of Verbs and Nouns in French 18-Month-Olds

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In this experiment using the conditioned head-turn procedure, 18-month-old French-learning toddlers were trained to respond to either a target noun (“la balle”/the ball) or a target verb (“je mange”/I eat). They were then tested on target word recognition in two syntactic contexts: the target word was preceded either by a correct function word (“une balle”/a ball or “on mange”/they eat), or by an incorrect function word, signaling a word from the other category (“on balle”/they ball or “une mange”/a eat). We showed that 18-month-olds exploit the syntactic context on-line to recognize the target word: verbs were recognized when preceded by a personal pronoun but not when preceded by a determiner and vice-versa for nouns. These results suggest that 18-month-olds already know noun and verb contexts. As a result, they might be able to exploit them to categorize unknown words and constrain their possible meaning (nouns typically refer to objects whereas verbs typically refer to actions).

## INTRODUCTION

To construct their lexicon, infants must among other things segment the continuous speech signal into words and assign a meaning to each word. In addition to the well-demonstrated use of visual

and socio-pragmatic cues (e.g., Baldwin et al., 1996; Tomasello, 2000), Lila Gleitman and her co-workers suggested that being able to keep track of the syntactic structures in which words occur would also help children to learn the meaning of words, a hypothesis called *syntactic bootstrapping* (Gleitman, 1990; Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2005; Landau & Gleitman, 1985). This hypothesis raises the question of how to bootstrap the syntactic bootstrapper: What kind of syntactic structures can be learnt by infants sufficiently early to be exploited for lexical acquisition?

Several experiments showed that 2- to 3-year-old children can exploit verb argument structure and inflectional morphology to infer the meaning of new words (Fisher, 1996; Fisher, Gertner, Scott, & Yuan, 2010, for English; Göksun, Küntay, & Naigles, 2008, for Turkish; Naigles, 1996; Naigles & Kako, 1993; Yuan & Fisher, 2009). At an even younger age, infants were found to be sensitive to function words and morphemes. Function words, which are short, unstressed, highly frequent, and typically occur at the edges of prosodic boundaries (Shi, Morgan, & Allopenna, 1998), start to be recognized between 6 and 9 months of age (Höhle & Weissenborn, 2003; Shi, Cutler, Werker, & Cruickshank, 2006). They are used to segment adjacent content words (Shi & Lepage, 2008) and to compute syntactic structure on-line at 2 years (Bernal, Dehaene-Lambertz, Millotte, & Christophe, 2010).

The early availability of function words led researchers to propose that infants could exploit them to assign syntactic and semantic properties to words (Christophe, Guasti, Nespors, Dupoux, & van Ooyen, 1997; Christophe, Millotte, Bernal, & Lidz, 2008; Fisher, Klingler, & Song, 2006; Shi, 2005). More specifically, function words may allow infants to categorize unknown content words, and constrain their possible meanings. For instance, determiners typically co-occur with nouns while pronouns typically co-occur with verbs. Since nouns mostly refer to objects and verbs mostly to actions, knowing the syntactic category of an unknown content word may help children to guess its meaning by constraining the possible referent, either an object or an action.

Several experiments showed that toddlers are indeed able to exploit function words to constrain meaning at around 2 years of age (e.g., Fisher et al., 2006; Hall, Waxman, Brédart, & Nicolay, 2003; Waxman & Booth, 2001). In particular, three recent experiments show that toddlers map a new word presented in a verb context to an action rather than to an object (Bernal, Lidz, Millotte, & Christophe, 2007, in French at 23 months; Oshima-Takane, Ariyama, Kobayashi, Katerelos, & Poulin-Dubois, in press, in Japanese, at 20 months; Waxman, Lidz, Braun, & Lavin, 2009, in English at 24 months). For instance, in Bernal et al. (2007), French 23-month-olds were taught a new word either in a verb context, that is, preceded by a pronoun (e.g., *Regarde ! elle dase ! / Look! It's dasing!*), or in a noun context, that is, preceded by a determiner (*Regarde ! c'est une dase ! / Look! This is a dase!*), while watching a video of an object performing a simple action (e.g., an apple turning on itself). When given a choice between two pictures with the same object performing either the familiar action (e.g., turning) or a new action (e.g., bouncing), children trained with the verb context pointed more to the familiar action while children trained with the noun context preferred the new action (novelty preference). Thus, the same unknown word placed in different syntactic contexts, that is, after a determiner or a pronoun, received a different meaning (see also Parisse, Veneziano, & Delacour, 2010, for an experiment showing that French 2-year-olds distinguish between known noun/verb homophones such as “une ferme/je ferme” *a farm/I close*, depending on their syntactic context).

Work with younger infants showed that 14- and 16-month-olds expect nouns after determiners but are not yet able to use pronouns to predict the occurrence of verbs (Höhle, Weissenborn,

Kiefer, Schulz, & Schmitz, 2004 in German; Shi & Melançon, 2010, in French). For instance, Shi and Melançon (2010) used a visual fixation paradigm and familiarized 14-month-olds with two pseudowords (“mige” and “crale”). Half of the children heard both pseudowords in a noun context, that is, preceded by determiners (“ton”/your and “des”/indefinite plural article), while the other half heard the same pseudowords in a verb context, that is, preceded by pronouns (“je”/I and “il”/he). All children were tested on the same words preceded either by a new determiner (“le”/the) or by a new pronoun (“tu”/you) leading to two syntactically correct utterances and two syntactically incorrect ones. Infants familiarized with the noun context listened longer to incorrect utterances, that is, with pronouns, thus showing a novelty preference. Infants are thus surprised when a word that used to be preceded by a determiner appears preceded by a pronoun later. In contrast, infants familiarized with the verb context showed no listening time differences, thus failing to use pronouns to build expectations as to the context of unknown content words. Congruent with the result that toddlers exploit determiners, English-learning 18-month-olds were shown to use the determiners of their language to recognize known nouns (Kedar, Casasola, & Lust, 2006; Zangl & Fernald, 2007). In a preferential looking paradigm, toddlers looked faster toward the picture of a target noun when this noun was preceded by a determiner versus an incorrect function word like “and” or a nonce function word like “el” (Kedar et al., 2006). They also looked longer at the congruent picture when the target noun was preceded by a determiner compared to a nonce article (Zangl & Fernald, 2007).

To sum up, determiners start to be classified together and associated with nouns from 14 months of age. On the other hand, the link between pronouns and verbs has not been shown for children under the age of 20 months (Bernal et al., 2007, in press; Waxman et al., 2009). There are several reasons why verbs may be harder to learn than nouns: they are conceptually more complex and occur in more varied contexts (see discussion in Höhle et al., 2004; Shi & Melançon, 2010). Nevertheless, younger toddlers do learn some verbs (Fenson et al., 1994), and it is possible that they have gathered relevant verb contexts.

Here, we tested French 18-month-olds’ ability to exploit the syntactic context to recognize nouns and verbs, using a Conditioned Head Turning technique. We tested whether toddlers expect determiners to be followed by nouns and pronouns to be followed by verbs. Half of the children were trained to turn their head for a noun (“balle”/ball in “la balle, des balles” / *the ball, balls*) and the other half for a verb (“mange”/eat in “tu manges, on mange” / *you eat, we eat*). They were tested on three different types of sentences. Correct sentences contained the target word preceded by a correct function word (i.e., preceded by a determiner if trained on “balle” – “j’adore les balles en mousse”/I love foam balls – or a pronoun if trained on “mange” – “Pierre, il mange du chocolat”/Pierre, he eats chocolate). Incorrect sentences contained the target preceded by an incorrect function word (these sentences were created by exchanging the target nouns and verbs from the previous sentences, for example, \*“(Pierre, il balle du chocolat)”/\*Pierre he balls chocolate, where the target noun is preceded by a pronoun, or \*“(j’adore les manges en mousse)”/\*I love foam eats). Last, distractor sentences did not contain the target at all (e.g. “j’adore les fraises au sucre”/I love strawberries with sugar, or “demain tu chantes chez Paul”/tomorrow you sing at Paul’s).

Given the literature reviewed above, we expect that the noun group children should turn their head more often for the correct context (. . . la balle . . .) compared to the incorrect context (. . . je balle . . .) and thus exploit the determiner to improve their recognition of the target noun. We should therefore replicate with a new technique the results obtained with French-learning

14-months-olds (Shi & Melançon, 2010), German-learning 16-months-olds (Höhle et al., 2004), and English-learning 18-months-olds (Kedar et al., 2006; Zangl & Fernald, 2007). The noun group thus allows us to test the efficiency of our paradigm: since this paradigm involves a purely auditory word detection task, toddlers might interpret the task as a detection of the phonological form of the target word, rather than a detection of the word itself. In that case, they would show no difference between correct and incorrect contexts, since the phonological form of the target word is present in all of these sentences. In contrast, if children are capable of exploiting the target word's specific syntactic context to recognize it faster, we will be able to conclude that children are not only recognizing the phonological form /bal/ of the target but really the word "balle."

In addition, if the noun group shows a significant advantage for the correct context over the incorrect one, the verb group will allow us to test whether 18-month-olds use pronouns to facilitate verb recognition, something that has not been done before (14- and 16-month-olds failed to use pronouns to predict verbs and 18-month-olds were tested only on nouns). If the target verb is recognized equally often whether preceded by a correct or an incorrect function word, we will conclude that pronouns do not yet promote the recognition of verbs. In contrast, children may recognize the target verb more often when it is preceded by a pronoun than by a determiner; this will show us that the function word preceding the target verb is exploited to facilitate its recognition. Furthermore, we will be able to directly compare toddlers' performance on nouns and verbs, and therefore test whether nouns benefit more from their immediate contexts than verbs, as suggested by the existing literature.

## EXPERIMENT

### Participants

Thirty-six monolingual French-learning 18-month-old toddlers participated in this study (age range 17 months 14 days to 18 months 25 days; mean 18 months 2 days). They performed a two-session experiment using the Conditioned Head Turning Paradigm. They were split in 2 groups: 18 toddlers were trained on nouns and 18 on verbs. The data from another 18 children who completed the second session were excluded from the analysis because they showed no evidence of having grasped the word detection task (nine in the noun group and nine in the verb group): they did not turn their head more often for correct sentences (where the target word was correctly inserted) than for distractor sentences (where no target word was inserted). In addition, 108 toddlers were tested but did not complete the first session: 60 were discarded on short phrases and 48 on short sentences, because of lack of interest, or fear, because they were not cooperative (illness, fatigue), or because they did not reach criterion within 40 training trials (see procedure). Of those toddlers who completed the first session with success, 2 did not come back for the second session, 3 were discarded due to technical problems, and another 22 toddlers did not finish the second session because they were either not interested in the reinforcement anymore, or fussed out before completing the session. Several factors account for this high drop-out rate: the experiment takes place in two separate sessions, each of these sessions is very long (10–20 minutes for the first session and 20 minutes for the second one), and it is difficult to get 18-month-old toddlers to sit quietly through an experiment. In addition, the task itself is difficult, since toddlers have to divide their attention between the experimenter sitting in front of them and the audio stimuli and

the reinforcers on their left. Similar drop-out rates were observed in other experiments relying on the same technique (word detection implemented with a 2-session conditioned head-turning technique, Gout, Christophe, & Morgan, 2004, with 13-month-old infants; Millotte et al., 2010, with 16-month-old toddlers). A comparison between drop-out rates in these three studies (including the present one) suggests that the older the children, the higher the drop-out rate. This could be because older children are very keen to interact directly with the experimenter and less likely to stay still while looking passively at someone playing silently in front of them.

## Stimuli

Children were tested on three different types of sentences: 12 contained the target word in its proper position, that is, always preceded by a grammatical word corresponding to its syntactic category (correct context), twelve contained the target word in an incorrect position, that is, always preceded by a function word inconsistent with its syntactic category (incorrect context), finally 12 sentences did not contain the target word at all (distractor sentences). Examples are shown in Table 1. Incorrect sentences were created by exchanging the target nouns and verbs from correct sentences, so that correct sentences for the noun group were identical to incorrect sentences for the verb group except for the target word. Similarly correct sentences for the verb group served as incorrect sentences for the noun group.

All stimuli were recorded using infant directed speech by a native speaker of French (the last author). Whole sentences were recorded in pairs (for instance a correct noun sentence was recorded together with its corresponding incorrect verb sentence) using the same intonation and rhythm. Since the stimuli were produced naturally rather than cross-spliced, we checked for differences in duration, fundamental frequency and root mean square of the amplitude for the target word, the preceding function word and the following word. No significant differences between correct and incorrect contexts were found for each word and each variable. Table 2 shows the mean values and standard errors for each of these acoustic variables.

## Group Assignment and Counterbalancing

Children were assigned to either the noun or the verb group. Each group was split in two halves that differed in the function words that were presented during the training session. Half of the

TABLE 1  
Example of Stimuli for the Three Contexts (Correct, Incorrect, and Distractor) in Both Groups of Children  
(Trained with Noun or with Verb)

	<i>Noun Group Target "balle"/ball</i>	<i>Verb Group Target "mange"/eat</i>
Correct context	"J'adore <u>les balles</u> en mousse." <i>I like foam balls.</i>	"Demain, <u>tu manges</u> chez moi." <i>Tomorrow, you eat at my place.</i>
Incorrect context	*"Demain, <u>tu balles</u> chez moi." <i>*Tomorrow, you ball at my place.</i>	*"J'adore <u>les manges</u> en mousse." <i>*I like foam eats.</i>
Distractor sentences	"J'adore les fraises au sucre" <i>I love strawberries with sugar.</i>	"Demain tu chantes chez Paul" <i>Tomorrow, you sing at Paul's</i>



TABLE 2

Acoustical Analyses of Duration, Maximum Fundamental Frequency (F0), and Root Mean Square (RMS) of the Amplitude for the Function Word Preceding the Target Word, the Target Word, and the Word Following the Target Word, Comparing Correct and Incorrect Contexts. The T-value for the Difference between Correct and Incorrect Sentences Was Always Below 1

		<i>Correct</i>		<i>Incorrect</i>		<i>Difference</i>
		<i>Mean</i>	<i>(std error)</i>	<i>Mean</i>	<i>(std error)</i>	<i>Correct-incorrect</i>
Duration (ms)	Function word	203	(12.1)	213	(12.2)	-10
	Target word	436	(14.9)	425	(23.3)	11
	Next word	256	(51.6)	282	(57.6)	-26
F0 <sub>max</sub> (Hz)	Function word	276	(9.3)	274	(7.8)	2
	Target word	346	(9.5)	341	(8.3)	6
	Next word	300	(11.9)	296	(11.0)	4
RMS (Pa)	Function word	0.091	(0.008)	0.089	(0.008)	0.002
	Target word	0.100	(0.008)	0.093	(0.004)	0.007
	Next word	0.075	(0.006)	0.066	(0.006)	0.009

noun group children were trained on “la balle”/ *the ball* (*feminine singular definite article*) and “des balles”/ *balls* (*plural indefinite article*) and the other half were trained on “une balle”/ *a ball* (*feminine singular indefinite article*) and “les balles”/ *the balls* (*plural definite article*). Similarly, for the verb group children, half were trained on “je mange”/ *I eat* and “il mange”/ *he eats*, and the other half on “tu manges”/ *you eat* and “on mange”/ *we eat*. All children were tested on the same test sentences that contained all four determiners and all four pronouns. As a result half of the test sentences they heard contained function words that they heard during training (familiar), and half contained function words that had not been presented during training (not used during familiarization). This familiarity difference will allow us to test whether children locate only bigrams “trained function word + target word,” that is, “la balle,” or whether they respond specifically to the target word and are thus capable of generalizing their response to other appropriate function words (new contexts).

## Procedure

The experimental procedure was a two-session variant of Conditioned Head-Turning (Gout et al., 2004; Millotte et al., 2010). Each session was divided into two parts. In the first session (training), children were trained first on short phrases (function word + target word, e.g., “la balle”/ *the ball*), then on short sentences (e.g., “la balle est jolie”/ *the ball is beautiful*). If the child reached a predefined criterion, he came back for a second session (eight days mean interval between the two sessions). This second session started with a review phase to remind the child of the task; he then completed the test phase per se.

Throughout both sessions, toddlers were seated on their parent’s lap at a small table. An assistant seated directly in front of the child maintained toddlers’ attention by silently displaying and manipulating an assortment of toys on the table. The loudspeakers and the motorized stuffed animals that provided reinforcement were located 90° to the left of the child, about 1.5 meters



away. A video camera was located directly above the loudspeakers. In the control room, the experimenter observed the toddler on a video monitor and judged whether he looked into the camera. Throughout all sessions, parent and assistant listened to acoustic masking (a hubbub of people talking together in different languages) over noise-attenuation headphones. At any time the experimenter could ask the assistant to modulate her behavior according to the toddler's, via a microphone connected to the assistant's headphones.

When the toddler's attention was focused in front of him, that is, on the toys that the assistant was showing, the experimenter initiated a trial by pressing the left mouse button. If the toddler turned his head toward the loudspeakers, the experimenter pressed the right mouse button to signal a head-turn. The reinforcement was delivered by the computer only if it was an appropriate head-turn (i.e., to a target word).

### First Session: Training

During the first training phase, toddlers heard a continuous series of short phrases, as a background stimulation, consisting of a function word and a content word (e.g., “une balle . . . les balles . . .” for the verb group and “je mange . . . il mange . . .” for the noun group), separated by a 1000ms ISI, and presented at a comfortable listening level (68dB SPL-b). When the child focused on the toys in front of him, the experimenter initiated a target trial. Background stimulation was then replaced by a triplet of target words (i.e. “je mange . . . je mange . . . il mange” for the verb group, and “une balle . . . les balles . . . une balle” for the noun group) presented 12dB louder. Since the target words were louder, the child usually turned his head spontaneously toward the loudspeaker. The experimenter signaled a head-turn by pressing the right mouse button. When the child turned his head correctly toward the loudspeakers at any time during the triplet of target words (with an average duration of 6.13s), a stuffed animal appeared for a reinforcement window of 3500ms and the loudness of the next trial went down by 3dB. If he failed to turn three times in a row, the sound level went one step louder (+3dB). When the target word reached the same loudness as background and the child successfully responded to the target twice in a row, the criterion phase started. The aim of this phase was to ensure that the child responded to the words themselves and not to the difference in loudness. In this phase, when the experimenter launched a trial, the computer played either target words or background words. The experimenter was blind to the nature of the trial (target or background) and just reported whether the child turned his head or not. The child's response was coded as correct if he turned during a target trial or refrained from turning during a background trial; it was coded as incorrect whenever he failed to respond to a target trial or turned for a background trial. If the child failed successively three times, he went back in the first training phase. If the child responded correctly for 7 out of 8 consecutive trials, or for 80% of 12 consecutive trials, the child continued to the second part of the first session: training on short sentences. If the child did not reach one of these success criteria within 40 trials, the experiment was ended. The procedure of the second part of the training session was equivalent to the first one except that the stimuli (target and background) were short sentences (e.g., “la balle est jolie”/ *the ball is lovely* or “je mange une pomme”/ *I eat an apple*). This second part of the training session was aimed at smoothing the transition between the very beginning of training (short phrases, e.g., “la balle” / *the ball*) and the test session that uses longer sentences. If the child succeeded in this criterion phase, that is, responded correctly for 7 out of 8 consecutive

trials, or for 80% of the trials, parents were asked to come back for the second session a few days later. Toddlers who did not reach one of these criteria within 40 trials were rejected.

### Second Session: Test

The review phase, which began this session, used the same short sentences as the ones used in the second half of the training session, but without background. When a trial was initiated by the experimenter, a sentence randomly chosen by the computer was played (50% with target, 50% without target; sentences without target were noun sentences for the verb group and verb sentences for the noun group). The experimenter knew if the sentence contained the target word or not. The first sentence was played 12dB louder than the test sentences. If the child's behavior was correct (i.e., he turned his head for a sentence containing the target word and was rewarded by a 2500ms reinforcement or did not turn his head for a sentence which did not contain the target word), the next sentence was played 4dB lower. If the child made two mistakes in a row, the loudness increased by 4dB. When the child's behavior was correct twice in a row at test sentence level, the program automatically moved to the test phase. The interval between sentences was at least 1000ms.

In the test phase when the experimenter initiated a trial, the computer selected a sentence of one of three types (correct context, incorrect context, distractor sentence) at random. The experimenter was blind to the type of sentence played. Reinforcement was displayed only for correct sentences if the child turned his head. The reinforcement window started from the onset of the target word and lasted 2500ms (only head-turns occurring during this time period were counted as responses to the target word). If the experimenter observed that the child was less attentive, she could choose to come back to the review phase to catch his attention. To complete the session, the child had to pass through each of the thirty-six test sentences once. Figure 1 shows an overview of the different phases of the experiment.

### Analysis

In addition to online coding, the results from all the toddlers who finished the second session were recoded off-line. This recoding was carried out to avoid cases where the child turned his head, by chance, just before the onset of the target word (in addition, responses given between 0 and 250ms

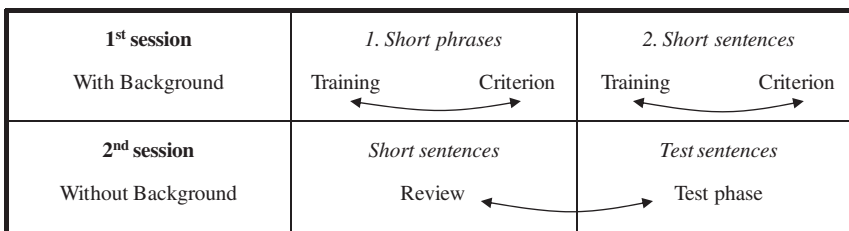


FIGURE 1 Organization of the experiment.

from the beginning of the target word were not considered as responses to the target word, given that it takes about that time to launch a saccade). Whenever this happened, the corresponding data point was considered as missing data.<sup>1</sup> The recoding also allowed us to include head-turns that occurred towards the end of the 2.5s window and were not counted on-line because of the reaction time of the experimenter. Overall, 15% of the sentences changed status.

## Results

Figure 2 shows the mean percentage of head-turns by test sentence type and Target Category (Noun vs. Verb). Two ANOVAs were performed on the mean percentage of head-turns, one by subjects and one by items. The by-subjects ANOVA had two between-subjects factors: Target Category (toddlers from the Noun group or from the Verb group), and the counterbalancing factor Group (group 1 or 2 trained with different function words), as well as two within-subject factors: Condition (Correct context, Incorrect context or Distractor sentences) and Familiarity (Familiar: preceded by a function word used during training, Non-Familiar: preceded by a function word not used during training). The by-item ANOVA had three within-item factors: Target Category, Condition and Familiarity.

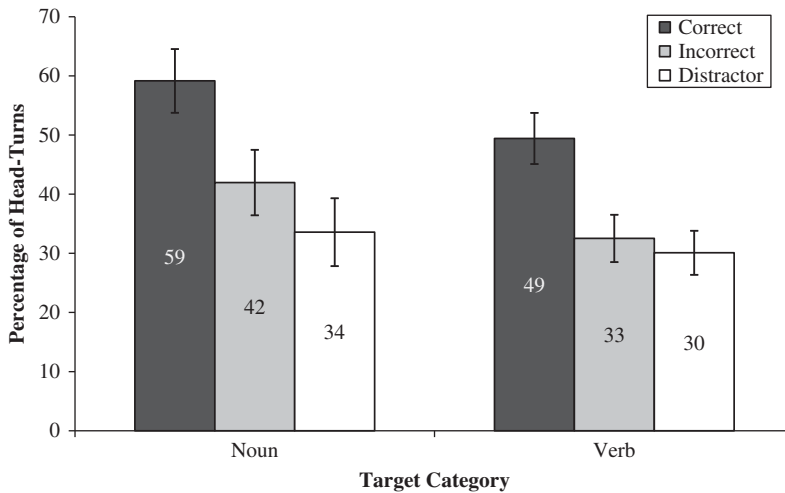


FIGURE 2 Percentage of head-turns as a function of target category (toddlers trained with nouns or verbs) and sentence type (correct, incorrect, distractor).<sup>2</sup>

<sup>1</sup>Because some sentences were dropped from the analysis, not all children had 12 sentences per condition: the number of sentences per condition varied between 12 and 9 (for the more restless kids). Since 6 head-turns out of 12 possible responses is a smaller response rate than 6 out of 9 possible sentences, we present percentages instead of raw numbers.

<sup>2</sup>The high false alarm rate (around thirty per cent head-turns for distractor sentences) can be related to the attractiveness of the reinforcers. Children tended to look toward the stuffed animals to check if they were visible.

The analyses of variance revealed a main effect of Condition ( $F_1(2,64) = 33, p < 10^{-9}$ ,  $F_2(2,22) = 15, p < 10^{-4}$ ) with more responses to correct sentences (54%) than to incorrect sentences (37%) and distractor sentences (32%). The Target Category factor showed a main effect only in the by-item analysis ( $F_1(1,32) = 2.3, p = 0.14$   $F_2(1,11) = 8, p < 0.01$ ), reflecting the fact that toddlers from the noun group responded slightly more often overall than toddlers from the verb group (effects of subject groups are likely to be significant in a by-item analysis). Crucially, Target Category did not interact with Condition ( $F_1(2,64) = 1.1, F_2(2,22) < 1$ ), showing that the noun and the verb group behaved in the same way, nor did it interact with Familiarity ( $F_1(1,32) = 3, p < 0.09; F_2(1,11) < 1$ ).

The effect of Familiarity was only marginally significant by subjects ( $F_1(1,32) = 3.14, p = 0.09, F_2(1,11) = 1.1$ ), reflecting a small tendency to respond more to sentences containing function words used in training than to sentences containing function words not used in training. Crucially, no interaction between Condition and Familiarity was found ( $F_1(2,64) < 1, F_2(2,22) < 1$ ). The effect of Condition was observed equally for both kinds of function words (see fig 2 for a breakdown with familiarity of the function word). Even though the interaction between Condition and Familiarity was not significant, we conducted the same ANOVAs as above restricted to function words not used in the training phase, so as to study only generalization. The Condition factor was still highly significant ( $F_1(2,64) = 13.9, p < 10^{-5}, F_2(2,22) = 5.7, p < 0.01$ ). Thus, children did not simply recognize the trained bigrams “function word/target word” but were also capable of identifying the target word even when it was preceded by a function word not used during the training session (see Figure 3).

Since no significant differences were found between both groups of children or between function words used during training, we focused on differences between conditions. We performed three post-hoc comparisons (with a Bonferroni correction): the difference between Correct

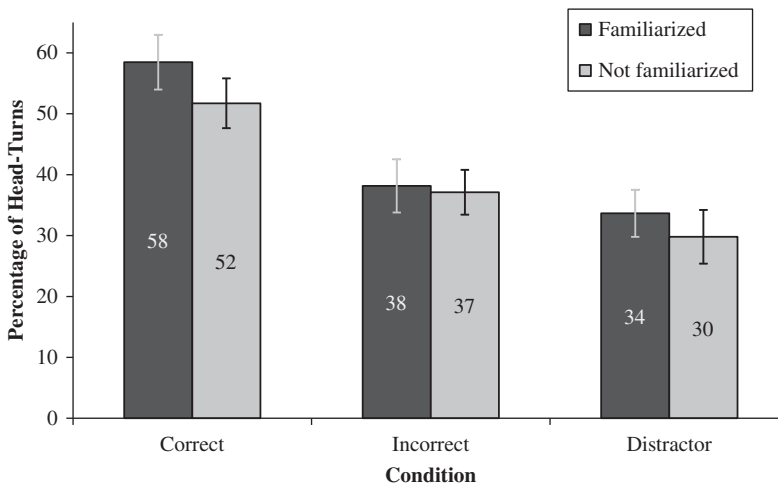


FIGURE 3 Percentage of head-turns as a function of the function word preceding the target (i.e., used in familiarization or not), and of sentence type (correct, incorrect, distractor).

and Distractor sentences was highly significant (effect size 22.5%,  $F_1(1,32) = 59$ ,  $p < 10^{-7}$ ,  $F_2(1,11) = 27$ ,  $p < 0.001$ ) as well as the difference between Correct and Incorrect sentences (effect size 17.0%,  $F_1(1,32) = 40$ ,  $p < 10^{-5}$ ,  $F_2(1,11) = 15$ ,  $p < 0.008$ ). This last result is particularly striking, since toddlers behaved differently for sentences that all contained the phonological form of the target word: the syntactic context in which this word was inserted heavily influenced toddlers' behavior. The last comparison between incorrect and distractor sentences was not significant (effect size 5.4%,  $F_1(1,32) = 3.4$ ,  $p = 0.21$ ,  $F_2(1,11) = 1.3$ ,  $p > 0.8$ ): children did not turn their head significantly more often for incorrect sentences which effectively contained the phonological form of the target albeit in an incorrect context, than for distractor sentences which did not contain the target word at all.

Since toddlers had a 2.5s-window in which to give their response, the observed results could at least in part be due to their processing of the words following the critical word. If this were the case, toddlers might reject some of the sentences because the target word does not make sense with the words that follow, rather than because they built specific expectations based on the function words that preceded the target word. For instance, in “je balle une petite pomme” / *I ball a small apple*, toddlers might have trouble accessing the noun “balle” not just because it is incorrectly preceded by a pronoun but also because its meaning does not fit with the following words.<sup>3</sup> To evaluate toddlers' responses before they had access to the following words, we conducted an additional post-hoc analysis in which we took into account only those responses given before the end of the critical word, plus a decision time (300 ms), plus a saccade-launching time (300ms).<sup>4</sup> These fast responses represented 47% of all responses. Figure 4 shows the results per condition

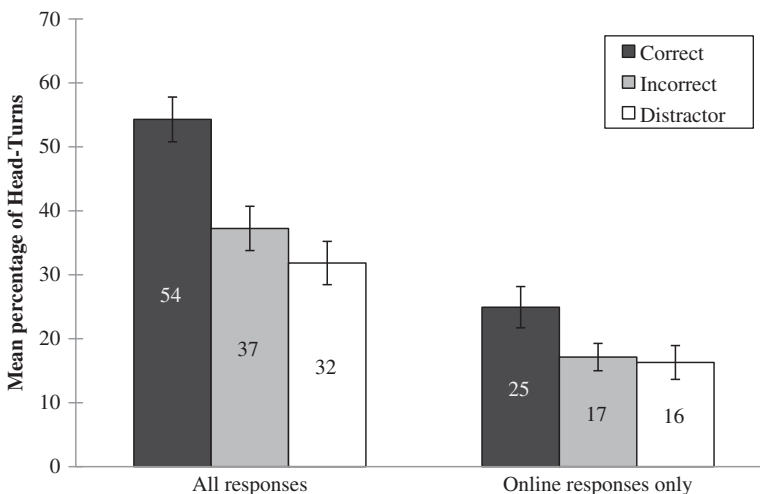


FIGURE 4 Percentage of head-turns as a function of target category: comparison between all responses and online responses.

<sup>3</sup>We thank an anonymous reviewer for suggesting this additional analysis.

<sup>4</sup>This window was computed for each item separately, because the target words varied in duration. Since mean target duration was 430.5ms, the window for fast responses lasted 1030.5ms on average.

both for all responses (with the same data as in Figures 1 and 2) and restricted to these fast, or “on-line,” responses, given before the end of the target word. Just as in the main analysis, we conducted a by-subjects ANOVA with the intra-subject factor Condition (3 levels: Correct, Incorrect, Distractor) the counterbalancing inter-subject factor Group and the inter-subject factor Target Category (Noun vs Verb). There was a main effect of Condition  $F_1(2,64) = 6.6$ ,  $p < 0.002$ , with toddlers responding significantly more for Correct contexts than for Incorrect or Distractor sentences. No other main effect or interaction was significant. Three post-hoc t-tests (with Bonferroni correction) were performed. The difference between Correct and Incorrect contexts, and between Correct and Distractor contexts were significant (respectively  $t(35) = -2.6$ ,  $p < 0.04$  and  $t(35) = 2.96$ ,  $p < 0.02$ ) but the difference between Incorrect and Distractor contexts was not  $t(35) < 1$ .

## Discussion

We used the conditioned head-turning paradigm to determine whether 18-month-old toddlers are able to use the function word preceding a target word to build expectations as to its syntactic category (noun vs. verb) and therefore improve its identification. More precisely, we tested whether determiners facilitate the detection of a noun target, and whether personal pronouns facilitate the detection of a verb target.

The target word was better identified when used in a correct syntactic context compared to an incorrect context where the target’s phonological form appeared preceded by an incongruent function word. Thus, target nouns were recognized more often when preceded by a determiner rather than by a personal pronoun, whereas target verbs were recognized more often when preceded by a pronoun rather than by a determiner. These results show that in our paradigm, toddlers did not perform a purely phonological recognition task; if that were the case, they should have responded to the target word irrespective of its syntactic context. This paradigm thus allows us to test toddlers’ word recognition rather than simple phonological form matching. Our results are congruent with those obtained with picture-word matching for nouns (Kedar et al., 2006; Zangl & Fernald, 2007), showing that English-learning 18-month-olds expect a noun after hearing a determiner. Crucially, we also extended this result to verb processing, showing that French 18-month-olds expect a verb to occur after hearing a personal pronoun, but not after hearing a determiner.

This result is new because of all the studies that tried to test whether toddlers were aware that verbs occur in specific syntactic contexts, only those with toddlers aged 20 months or older succeeded (Bernal et al., 2007, in French; Oshima-Takane et al., in press, in Japanese; Waxman et al., 2009, in English). Two studies with younger infants failed: Shi and Melançon (2010) showed that French 14-month-olds recognized a class of determiners but not a class of pronouns. Similarly, Höhle et al. (2004) showed that German 16-month-olds presented with a new word preceded by a determiner recognized that word when it occupied a noun position in sentences, while they were not able to recognize a verb (initially preceded by a pronoun) when it occupied a verb position in sentences. In contrast, in our results, we found no asymmetry between nouns and verbs in French 18-month-olds. Thus, by the age of 18 months, French-learning toddlers are able to exploit pronouns to improve their identification of a target verb.

The function words that had been used during training (“familiarized”) did not trigger better recognition than the function words not used during training (“not familiarized”). Thus, the task was correctly understood as the detection of the lexical item “balle”/ball or “mange”/eat rather

than as the detection of the word strings “function word + target” heard during the training session. ANOVAs restricted to nonfamiliarized function words yielded the same condition effect as the overall ANOVA: the target word was better recognized when preceded by a correct function word than when preceded by an incorrect function word, even though none of these function words had been trained in the experiment.

Moreover, an analysis restricted to online responses, responses that were triggered before the end of the target word, showed the same pattern of results as the overall analysis (Figure 3). This shows that even when they reached their decision on the basis of only the target word and its preceding context, toddlers processed correct and incorrect sentences differently. Toddlers thus exploited the context immediately preceding the target word, on-line, to recognize it.

We also checked that the difference in recognition between correct and incorrect contexts could not be due to a learning effect during the course of the experiment. Indeed, children could have learned not to turn their head for incorrect contexts because those sentences were not reinforced during the test session. If this were the case, one would expect toddlers to initially turn their head for incorrect contexts, then notice that these were not reinforced and stop turning for them. In other words, we should observe a greater response rate for incorrect contexts at the beginning than at the end of the experiment. A post-hoc analysis revealed that this was not the case: toddlers responded similarly in the first and the last thirds of the experiment.<sup>5</sup> Their differential response rates to Correct and Incorrect contexts was thus not due to a learning effect.

Another alternative explanation for our results could be that toddlers are sensitive to stored frequent phrases. Thus, children would react more to the target word when it belongs to a familiar word sequence (a frequent string of words) than when it belongs to an unfamiliar word sequence (in incorrect contexts, the target word and its preceding function word do not normally co-occur). If this hypothesis is correct, toddlers should be better able to recognize familiar words when they are embedded within frequently heard sequences of words. We thus expect to find a positive correlation between the frequency of “function word + target word” strings in the input (computed from a French CHILDES corpus; Demuth & Tremblay, 2008)<sup>6</sup> and the percentage of head-turns. We did not find any correlation between frequency of occurrence and hit rate (see Table 3). This analysis supports our interpretation in terms of syntactic category knowledge and weakens the interpretation that the effect could be solely linked to stored frequent bigrams.

<sup>5</sup>To test for this learning effect, we analyzed separately the first four trials and the last four trials of the experiment for each condition. We conducted an ANOVA with two within-subject factors: Condition (with three levels: Correct, Incorrect, and Distractor) and First-Last (with two levels: First four trials vs. Last four trials). The ANOVA revealed a significant effect of Condition ( $F_1(2,70) = 20$ ;  $p < 10^{-7}$ ), reflecting the fact that toddlers responded more often for Correct sentences than for either Incorrect or Distractor sentences, as well as a significant First-Last effect ( $F_1(1,35) = 11$ ;  $p < 0,002$ ), that was due to the fact that toddlers responded less often overall towards the end of the experiment (probably because they got tired). Crucially, there was no interaction between these 2 factors, indicating that the effect of Condition was not significantly different in the First vs. Last trials ( $F_1(2,70) = 2.1$ ,  $p = 0.13$ ). If anything, the difference between Correct and Incorrect sentences was larger at the beginning of the experiment (First four trials: Correct 63.9%, Incorrect 42.4%, Distractor 41.7%) than at the end (Last four trials: Correct 46.5%, Incorrect 37.5%, Distractor 25.7%), probably because toddlers got more tired and distracted towards the end of the experiment. We thank an anonymous reviewer for this suggestion.

<sup>6</sup>This corpus is a transcription of mother-infant interactions from two families. Both children (Timothée and Marie) were recorded between the age of 1.5 and 2.5 years. The corpus contains around 200 000 tokens for around 26,500 utterances.



TABLE 3  
Item Frequency in the Input (CHILDES) and Its Correlation with the  
Head-turn Percentage

<i>Item</i>	<i>CHILDES Frequency</i>	<i>Head-turn Percentage</i>
La balle	40	66
Des balles	1	46
Une balle	6	45
Les balles	0	71
Je mange	4	44
Tu manges	17	40
Il mange	14	46
On mange	17	42
R <sup>2</sup>		0.04

Altogether, these analyses support our interpretation that 18-month-olds' word recognition was influenced, on-line, by the words that immediately preceded the target word. Van Heugten and Shi (2009) found a similar effect for gender-marked articles in 25-month-old French toddlers. In addition, a direct comparison between incorrect sentences, in which the target word was present but in an incorrect context, and distractor sentences which did not contain the target word, revealed a non-significant difference. Toddlers showed only a small tendency to respond more to incorrect sentences than to distractor ones. This result is particularly striking, because the full phonological form of the target word was present in the incorrect sentences but not in the distractor sentences, and one would expect toddlers to be tempted to respond to this phonological form. They behaved as if the target word in an incorrect context (e.g., "je balle"/*I ball*) bore little similarity to the real target word, the one they were monitoring. This result suggests that either they did not recognize the target word at all when it appeared in an incorrect context, or its recognition was much delayed.

Our study shows that French 18-month-olds are able to exploit pronouns to improve the processing of verbs. Congruent with our results, other studies showed that at the age of 18 months, toddlers are able to exploit verb-related morphological information. For example, 18- and 21-month-olds presented with two dynamic actions simultaneously while hearing either the grammatical form of a verb (e.g., dancing), an ungrammatical form (dancely) or a nonce form (dancelu), looked significantly longer to the picture representing the action while hearing the grammatical form of the verb compared to the two other forms, suggesting that correct morphology is useful for recognizing a known verb (Golinkoff, Hirsh-Pasek, & Schweisguth, 2001). In addition, 18-month-olds are sensitive to discontinuous dependencies such as between the auxiliary verb *is* and the verb ending *-ing* (Santelmann & Jusczyk, 1998). Using the Headturn Preference procedure, these authors showed that 18- but not 15-month-old infants looked longer to passages containing "*is verb-ing*" compared to passages containing the incorrect sequence "*\*can verb-ing*" (see also Höhle, Schmitz, Santelmann, & Weissenborn, 2006, for similar results in German). Similarly, Van Heugten and Shi (2009) showed that French 17-month-olds listened longer to sentences containing grammatical dependencies such as "*la coupile va conduire*" (*the<sub>SING</sub> nonword will<sub>SING</sub> drive*) than to sentences containing ungrammatical dependencies such as "*\*les coupiles va conduire*" (*the<sub>PL</sub> nonword will<sub>SING</sub> drive*). Since toddlers are sensitive to

discontinuous dependencies of this type, they may be able to exploit these to categorize unknown words (see Chemla, Mintz, Bernal, & Christophe, 2009, in French; Mintz, 2003, for the “frequent frames” hypothesis; Weisleder & Waxman, 2010, in Spanish). Taken together with these results showing sensitivity to verb-related morphological information, our demonstration that pronouns are exploited for on-line verb processing suggest that 18-month-olds may be able to use the morphosyntactic contexts in which verbs occur to enhance their processing.

Overall, our results and those of the literature (in several languages) suggest that by the age of 18 months, toddlers have a rather precise knowledge about the morphosyntactic contexts in which verbs and nouns occur. It is thus possible that they may use this knowledge in order to categorize unknown content words, which might help them infer that their meaning is probably related either to actions for verbs, or to object for nouns.

## CONCLUSION

We showed that 18-month-olds recognize a target word more often when it is preceded by a correct function word: toddlers turn their head more often for a target verb preceded by a personal pronoun in comparison to the same word preceded by a determiner, and for a target noun preceded by a determiner in comparison to the same word preceded by a pronoun. These toddlers, who are in the process of acquiring their lexicon, exploited online the syntactic context in which a word appears to recognize it.

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## APPENDIX: LIST OF THE EXPERIMENTAL SENTENCES

Noun target - Correct context: "balle" in noun position	Noun target – Distractor sentences	Noun target – Incorrect context: "balle" in verb position
1 La <u>balle</u> est rouge et verte <i>The ball is red and green</i> 2 C'est la <u>balle</u> de mon cousin <i>It is my cousin's ball</i> 3 La <u>balle</u> de Paul fait du bruit <i>Paul's ball makes noise</i> 4 Des <u>balles</u> sont tombées par terre. <i>Balls fell on the floor</i> 5 J'ai acheté des <u>balles</u> de tennis <i>I bought tennis' balls</i> 6 Il veut des <u>balles</u> rebondissantes <i>He wants bouncing balls</i> 7 Une <u>balle</u> a roulé dans l'herbe <i>A ball rolled in the grass</i> 8 J'ai vu une <u>balle</u> sous le lit <i>I saw a ball under the bed</i> 9 Je voudrais une <u>balle</u> pour ma fête <i>I would like a ball for my party</i> 10 Les <u>balles</u> de ping-pong sont légères <i>Ping pong balls are light</i> 11 J'adore les <u>balles</u> en mousse <i>I love foam balls</i> 12 Les <u>balles</u> flottent dans la piscine <i>The balls float in the pool</i>	La <u>fraise</u> est belle et fraîche <i>The strawberry is fine and fresh</i> C'est la <u>vache</u> de mon père <i>It is my father's cow</i> La <u>chaise</u> de Jeanne est en bois <i>Jane's chair is in wood</i> Des <u>vaches</u> sont tombées dans l'eau <i>Some cows fell in the water</i> J'ai mangé des <u>fraises</u> à la crème <i>I ate some strawberries with cream</i> Elle veut des <u>chaises</u> très confortables <i>She wants very comfortable chairs</i> Une <u>fraise</u> a poussé à l'ombre <i>A strawberry grew in the shade</i> J'ai pris une <u>chaise</u> pour m'asseoir <i>I took a chair to sit</i> Elle voudrait une <u>vache</u> pour jouer <i>She would like a cow to play with</i> Les <u>chaises</u> de Mamie sont belles <i>Granny's chairs are pretty</i> J'adore les <u>fraises</u> au sucre <i>I love strawberries with sugar</i> Les <u>vaches</u> marchent très lentement <i>Cows walk slowly</i>	Il <u>balle</u> une petite pomme <i>He balls a little apple</i> Pierre, il <u>balle</u> du chocolat <i>Pierre, he balls some chocolate</i> Il <u>balle</u> une glace au citron <i>He balls a lemon ice-cream</i> Je <u>balle</u> de la tarte aux fraises <i>I ball strawberry pie</i> A midi, je <u>balle</u> des saucisses <i>For lunch, I ball sausages</i> Ce soir je <u>balle</u> au restaurant <i>Tonight I ball at the restaurant</i> On <u>balle</u> une pizza au thon <i>We ball a tuna pizza</i> Ce soir on <u>balle</u> chez mamie <i>Tonight we ball at granny's</i> Aujourd'hui on <u>balle</u> du poisson <i>Today we ball some fish</i> Tu <u>balles</u> des gâteaux à la crème <i>You ball creams cakes</i> Demain tu <u>balles</u> chez moi <i>Tomorrow you ball at my place</i> Tu <u>balles</u> bien tes légumes verts <i>You ball well your green vegetables</i>
Verb target – Incorrect context: "mange" in noun position	Verb Distractor sentences	Verb target – correct context: "mange" in verb position
1 La <u>mange</u> est rouge et verte <i>The eat is red and green</i> 2 C'est la <u>mange</u> de mon cousin <i>It is my cousin's eat</i> 3 La <u>mange</u> de Paul fait du bruit <i>Paul's eat makes noise</i> 4 Des <u>manges</u> sont tombées par terre <i>Eats fell on the floor</i> 5 J'ai acheté des <u>manges</u> de tennis <i>I bought tennis' eats</i> 6 Il veut des <u>manges</u> rebondissantes <i>He wants bouncing eats</i> 7 Une <u>mange</u> a roulé dans l'herbe <i>A eat rolled in the grass</i> 8 J'ai vu une <u>mange</u> sous le lit <i>I saw a eat under the bed</i> 9 Je voudrais une <u>mange</u> pour ma fête <i>I would like a eat for my party</i> 10 Les <u>manges</u> de ping-pong sont légères <i>Ping pong eats are light</i> 11 J'adore les <u>manges</u> en mousse <i>I love foam eats</i> 12 Les <u>manges</u> flottent dans la piscine <i>The eats float in the pool</i>	Il <u>donne</u> un livre à Pierre <i>He gives a book to Pierre</i> Max il <u>marche</u> à reculons <i>Max, he walks backward</i> Il <u>chante</u> un air très joli <i>He sings a beautiful melody</i> Je <u>donne</u> des bonbons au chien <i>I give candies to the dog</i> Quand ça glisse, je <u>marche</u> lentement <i>When it is slippery, I walk slowly</i> Ce soir je <u>chante</u> à l'opéra <i>Tonight I sing at the opera</i> On <u>chante</u> à la fête foraine <i>We sing at the carnival</i> Ce soir on <u>donne</u> des gâteaux <i>Tonight we give cakes</i> A la plage on <u>marche</u> sur le sable <i>On the beach we walk on the sand</i> Tu <u>donnes</u> des cadeaux à ton frère <i>You give gifts to your brother</i> Demain tu <u>chantes</u> chez Paul <i>Tomorrow you sing at Paul's</i> Tu <u>marches</u> seul dans la forêt <i>You walk alone in the forest</i>	Il <u>mange</u> une petite pomme <i>He eats a little apple</i> Pierre, il <u>mange</u> du chocolat <i>Pierre he eats chocolate</i> Il <u>mange</u> une glace au citron <i>He eats a lemon ice-cream</i> Je <u>mange</u> de la tarte aux fraises <i>He eats strawberry pie</i> A midi, je <u>mange</u> des saucisses <i>For lunch, I eat sausages</i> Ce soir je <u>mange</u> au restaurant <i>Tonight I eat out</i> On <u>mange</u> une pizza au thon <i>We eat a tuna pizza</i> Ce soir on <u>mange</u> chez mamie <i>Tonight we eat at Granny's</i> Aujourd'hui on <u>mange</u> du poisson <i>Today we eat fish</i> Tu <u>manges</u> des gâteaux à la crème <i>You eat cream cakes</i> Demain tu <u>manges</u> chez moi <i>Tomorrow you eat at my place</i> Tu <u>manges</u> bien tes légumes verts <i>You eat well your green vegetables</i>