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Syntax Constrains the Acquisition of Verb Meaning

Savita Bernal
Laboratoire de Sciences Cognitives et Psycholinguistique
EHESS / CNRS / DEC-ENS, Paris, France

Jeffrey Lidz
Cognitive Neuroscience of Language Laboratory, Department of Linguistics
University of Maryland

Séverine Millotte
Laboratoire de Psycholinguistique Expérimentale, Geneva, Switzerland
and Laboratoire de Sciences Cognitives et Psycholinguistique
EHESS / CNRS / DEC-ENS, Paris, France

Anne Christophe
Laboratoire de Sciences Cognitives et Psycholinguistique
EHESS / CNRS / DEC-ENS, Paris, France
and Maternité Port-Royal, AP-HP, Faculté de Médecine
Université Paris-Descartes

Can infants use the syntactic context of an unknown word to infer that it is a verb, and thus refers to an action? Twenty-three-month-old French infants watching a moving object were taught novel verbs, within sentences that contained only function words (e.g. "il poune par là" / "it's pooning there"). Infants then watched two instances of the object undergoing either the familiar or a novel action and were asked to point towards the screen matching the novel verb. Infants correctly pointed more often towards the familiar action. To check that they did not simply perseverate in pointing at the familiar scene, control infants were taught novel nouns on the same visual stimuli (e.g. "un poune est là"/ "a poon is here"). Contrary to verb-learning infants, noun-learning infants

Correspondence should be addressed to Savita Bernal, LSCP, ENS, 29, rue d'Ulm, 75005 Paris, France. E-mail: savita.bernal@ens.fr

pointed more often to the novel action. These results confirm the hypothesis that function words, and more generally syntactic structure, support early lexical acquisition.

Learning novel words is not an easy task. Assigning a meaning to a word, even in the simplest situation (someone saying "look, that's a cat!" while pointing at a furry four-legged animal) is not straightforward. How is a child to know that this sequence of sounds refers to an animal and not, for instance, to its color or its movement (Quine, 1960)? Different hypotheses have been formulated as to how a child may restrict the set of hypotheses she entertains about the meaning of a novel word (for reviews, see Waxman & Lidz, 2006; Woodward & Markman, 1998). Among these, the Syntactic Bootstrapping hypothesis postulates that there exists a principled relationship between the meaning of a word and the syntactic structure in which it occurs and that these principles guide children's hypotheses about novel word meaning (Gleitman, 1990; Landau & Gleitman, 1985). On this view, some basic knowledge about syntax may help children identify the meanings of novel words. This hypothesis has received support from adult experiments (Gillette, Gleitman, Gleitman, & Lederer, 1999), as well as from toddlers (Fisher, Hall, Rakowitz, & Gleitman, 1994; Lidz, Gleitman, & Gleitman, 2003) and infants (Fisher, 2002; Naigles & Kako, 1993; Waxman & Booth, 2001). In all of these studies, the number and type of syntactic arguments provide information that is used by children to identify the meaning of a novel verb (except for Waxman & Booth, 2001, which deals with the nouns/adjective distinction).

While the existing literature indicates that children can use syntactic information to choose one event from several as the referent of a novel verb, the ability to do so depends on the child's having identified the verb category as one that potentially refers to events. A precursor to being able to use the number and type of arguments to determine which event a novel verb labels is to know that verbs prototypically refer to events. In the present study, we ask whether infants know that the syntactic category of a word is a cue to its meaning. Nouns generally refer to object categories, while verbs typically refer to event categories and adjectives to properties of objects (Brown, 1957; Grimshaw, 1981; Macnamara, 1982; Maratsos & Chalkley, 1980; Pinker, 1987). When do children know these patterns and what information do they use to identify the syntactic category of a word?

Syntactic categories are, by definition, distributional categories. What makes a set of words a category is that they occur in the same linguistic environments. One of the most reliable distributional properties of a syntactic category is the set of function words co-occurring with it. In French, for example, nouns generally co-occur with articles while verbs co-occur with pronouns and auxiliaries. Infants have been shown to be sensitive to function words very early on (Shi, Werker, & Morgan, 1999), to recognize the function words of their language

towards the end of their first year (Shafer, Shucard, Shucard, & Gerken, 1998; Shi, Werker, & Cutler, 2006) and to use them to facilitate word segmentation (Shi & Gauthier, 2005), sentence processing (Gerken, 1994; Gerken, Landau, & Remez, 1990; Kedar, Casasola, & Lust, 2006) and noun or verb categorization (Höhle, Weissenborn, Kiefer, Schulz, & Schmitz, 2004; Mintz, 2006). Recent corpus analyses have also supported the feasibility of categorizing content words using distributional co-occurrences between function and content words (Cartwright & Brent, 1997; Chemla, Mintz, Bernal, & Christophe, in press; Mintz, 2003; Mintz, Newport, & Bever, 2002).

Building on early work by Roger Brown (1957), showing that preschoolers can use the morphological markers surrounding a novel word as a cue to its meaning, we asked whether 23-month-old infants would attribute a different meaning to a novel word depending on the syntactic context in which it occurred. We chose 23-month-olds for two reasons. First, while children start to produce words in the vicinity of their first birthday, it is not until 24 to 30 months that infants begin to produce a sizeable number of verbs, and to use them systematically to refer to actions (e.g., eat, run), mental states (e.g., want, see) and relations (e.g., touch, move) (Bates et al., 1994; Caselli et al., 1995; Fenson et al., 1994; Gentner, 1981; Nelson, 1973).

Second, in many experimental verb-learning tasks, learners show surprising difficulties, many of which persist as late as three to five years of age, despite the fact that by 24 months they have begun to use verbs spontaneously and appropriately (Abbot-Smith, Lieven, & Tomasello, 2004; Behrend, 1995; Childers & Echols, 1996; Forbes & Poulin-Dubois, 1997; Hirsch-Pasek, Golinkoff, Maguire, & Imai, 2005; Imai, Haryu, & Okada, 2005; Kersten & Smith, 2002; Rice, 1980; Theakston, Lieven, Pine, & Rowland, 2001). This difficulty suggests that targeting children at the earliest stages of verb production could be highly informative about later difficulties in experimental tasks.

We defined the syntactic context of our novel words by varying the functional elements co-occurring with the word. In particular, we asked whether a novel word presented in a verb context would be taken to refer to an action. Twenty-three-month-old French infants were presented with video sequences featuring an object undergoing a simple action. Simultaneously, they heard sentences containing a novel word together with function words (as well as some attention-getters such as 'regarde!'/ '*look*!' that did not refer to any particular object or action in the visual display). There were only two potential referents for this novel word in the visual scene: the object and its action. If infants can use the syntactic context to identify the grammatical category of a novel word and thus infer its meaning, then they should think that it refers to the action when presented as a verb (ex: "Regarde, il *poune*" i.e. "Look, it('s) *blick(ing)*") but to the object when presented as a noun (ex: "Regarde le *poune*" i.e. "Look at the *blick*"). To test this, we used a paradigm derived from the well-known inter-modal preferential look-

ing paradigm (IPL); in this paradigm, we replaced the looking response with a pointing one.

MATERIAL AND METHOD

Subjects

32 infants from monolingual French-speaking homes participated in this experiment (18 girls, mean age 23;02 months, range 22;18 to 23;15), 16 in each of two groups (Experimental and Control). They had no known neurological or hearing deficits. The project was accepted by the Cochin Hospital Commission for Human Participants. Parents gave their informed consent before the study and completed a French version of the MacArthur CDI test (Kern, in press). There was no difference between the experimental and control groups in vocabulary scores (Experimental group, 223.6, Control Group, 225, $t(31) = 1.13$, $p = 0.27$). The results from 31 additional subjects were not analyzed for the following reasons: not pointing during warm-up (9, generally unwilling to interact with the experimenter), not pointing during training (12, generally losing interest in the setup), crying/fussing/not completing the experiment (6), mother speaking (1), technical problem (2), experimenter error (1).

Set up

Infants were seated in a high-chair, facing a large screen (1.5m by 2m), situated about 2m away, on which the stimuli were projected at the infant's eye-level. When two scenes were projected simultaneously on the screen (one on the left and one on the right), the angle between the center of both stimuli, from the infant's viewpoint, was about 30°. Infants were videotaped from a camcorder situated right in front of them, just above the top of the screen. Parents were seated behind the infants and were instructed not to talk to or distract infants. They wore headphones playing masking noise. A table (1m by 2m) was set between the infant and the screen. On the right of that table (from the infant's viewpoint), a chair was placed, that allowed an experimenter to sit with her back to the screen, facing the infant if she turned her head slightly to her right. This experimenter manipulated the puppet that asked the test questions. She did not wear masking headphones (since she had to speak in the experiment, she had to know when to take her turn), however, she was unable to see the screen and could therefore not influence the infant's reponses. A second experimenter, in another part of the room delimited by a curtain, out of sight of the infant, launched the various movies at the appropriate times. She could watch the infant on a monitor and check that the infant's pointing responses were visible on the video recording.

Procedure

Before the experimental session itself, during which infants were actually taught new words and tested on their comprehension, they went through two preliminary sessions to familiarize them with the set-up and the pointing task: warm-up and training. The warm-up session was aimed at eliciting pointing towards plastic animal toys (a dog, a cat, a hen and a giraffe, words known to infants of this age). During that phase only, the experimenter manipulating the puppet knelt behind the table, facing the infant (with the screen at her back), so that her face and shoulders were visible. She named all 4 animals, then placed 2 cardboard boxes on the table, their opening facing the infant, so that he could look inside but the experimenter (and the puppet) could not. Speaking in puppet-voice, the experimenter announced that the puppet loved to play hide-and-seek, and was going to play with its friends the animals. The puppet then made a show of leaving the scene (by going under the table), so that it would not see where the animals were hiding. Meanwhile, the experimenter, speaking in her normal voice (in a conspiratory tone), chose two of the animal toys, named them, and put them in each of the two boxes, speaking all the time (assuming she spoke to an infant named Tom: "Look, Tom, this is the dog! The dog is going in that box! Do you see the dog here, Tom?" "Oh, and this is the cat!" etc.; she used the infant's name a lot, to keep him engaged in the interaction). The experimenter then made the puppet come back and ask for one of the animals, speaking in puppet-voice again ("Hey, Tom, here I am again! I am looking for my friend the dog. Can you help me find the dog, Tom? I can't see him! Where is he? Can you show me where the dog is hiding, please, Tom?" etc.). The experimenter controlling the puppet went on asking questions until she managed to elicit a pointing response from the infant. If the infant did not point, the experimenter enrolled the parent to help, saying "Maybe Mummy knows where the dog is? Could you show me the dog, please, Mummy?", so that the parent would demonstrate what was expected from the infant. If the infant pointed towards the right animal, the puppet would thank him profusely, give him the toy as a reward and then go on to ask for the other animal. If the infant could point correctly to both objects in three instances of the game (not necessarily consecutive), he was allowed to continue with the training session. If not, he was excluded from this study. Throughout the warm-up phase, no effort was spared to make the infant point, and that phase lasted as long as the infant was not bored or restless.

The *training session* was aimed both at familiarizing the infant with the game on the screen and at teaching him to point towards an action. From that point on, the experimenter manipulating the puppet sat in her chair on the right of the infant, with her back to the screen. She had to rotate her torso and twist her neck to be able to glimpse at the screen and ask the right questions to the infant. Three short sequences displaying a woman performing familiar actions (eating, drinking

and giving) were shown to the infant while the puppet labelled the actions in a lively voice (cf. Table 1, "Look, that lady is drinking! Can you see? She's drinking! Oh! All gone!). Then the pointing game resumed. Two pictures of the same toys used during warm-up were shown simultaneously on either side of the screen. The puppet asked the infant to show it one of the animals ("Can you show me the dog, please, Tom? Where is the dog?"). If the infant pointed correctly on three instances, the pictures were replaced by two sequences of the familiar actions (e.g. a woman drinking on the left side and eating on the right side). The puppet asked the infant to point towards one action ("Can you show me the lady who is drinking? Show me the one who is drinking, please, Tom!"). When the infant had pointed correctly towards three actions, the experiment *per se* began.

During the *experimental session*, infants were taught novel words while looking at a video clip showing an object performing an intransitive action (e.g., a flower rotating). This session consisted of 4 trials, during which 4 novel words were presented together with 4 different object-action pairs (see 'materials' for details). Each trial included three phases: familiarization, contrast and test (see Table 2, design similar to Booth & Waxman, 2003). During the *familiarization phase*, infants were presented with three instances of the same object (e.g. a flower) undergoing the same motion (e.g. rotating). Meanwhile, they were taught a new verb, using short sentences that contained only that verb, some function words, and attention-getters (e.g. 'Look! it's pooning there'; see Table 2, left-hand column, for the full set of sentences in French). These sentences were uttered by a pre-recorded voice coming from loudspeakers. During the *contrast phase*, a different object was presented doing a different action (e.g. a frog sliding), produced with a negative sentence ('uh-oh, this one is not pooning!') and followed by the first object doing the familiar action, accompanied by an affirmative sentence ('Yeah! This one is pooning!'). In the *test phase*, infants were

TABLE 1
Script for the Training Session

For the verb warm-up	Regarde, la dame boit! Tu as vu? Elle boit! Hmm c'est bon…Oh! Elle est partie! *Look, the lady is drinking! Can you see? She's drinking. It looks good…Oh! all gone!"*
For the noun training	Oh! Tu peux me montrer le chien, s'il te plaît, Tom? Lequel est un chien? Il est où, le chien? Tu vois le chien? Montre-le moi! etc. *oh, can you show me the dog, please, Tom? Which one is a do ? Where is the dog? Can you see the dog ? Show it to me!*
For the verbs training	Oh! Tu peux me montrer la dame qui boit, s'il te plaît Tom? C'est laquelle, qui boit? Elle est où, celle qui boit? Montre-la moi! etc. *Oh! Can you show me the lady who's drinking, please, Tom? Which one is drinking? Where is the one who's drinking? Show her to me!*

TABLE 2
Example of Trials for Each Group of Subjects. Sentences Used for Both Groups were Closely Matched for Length and Position of the Target Word. In French, the Word is Pronounced Exactly the Same Way as When it is a Noun and When it is a Verb (3rd Person Singular Present Tense). A Second Contrast Phase and a Second Test Phase Followed (Identical Except for the Left/Right Ordering of the Test Phase, that Varied Quasi-Randomly)

Session	*Video*	*Experimental Group*	*Control Group*
FAMILIARIZATION (off voice, 20s)	Flower rotating (left)	Regarde, elle poune!	Regarde, c'est une poune
		Tu as vu ? Elle poune!	Tu as vu ? Une poune!
		Look! It's pooning!	*Look! This is a poon!*
		Do you see? It's pooning!	*Do you see? A poon!*
	Flower rotating (right)	Regarde maintenant!	Regarde maintenant!
		Elle poune par là!	La poune est là !
		Tu vois comment elle poune?	Tu vois ce que fait la poune?
		Now look! It's pooning there!	*Now look! The poon is there!*
		Do you see how it's pooning?	*Do you see what the poon is doing?*
	Flower rotating (left)	Oh, elle poune encore là!	Oh, la poune est encore là!
		Tu la vois qui poune?	Tu la vois cette poune?
		Oh! It's pooning there again!	*Oh! The poon is there again!*
		Can you see it pooning?	*Can you see this poon?*
CONTRAST (off voice, 10s)	Frog sliding (center)	Oh oh, celle-là ne poune pas!	Oh oh, celle-là n'est pas une poune!
		Ceci ne poune pas.	Ceci n'est pas une poune.
		Uh-Oh! That one is not pooning.	*Uh-Oh! That one is not a poon.*
		This is not pooning.	*This is not a poon.*
	Flower rotating (center)	Oui! Celle-là poune!	Oui! Celle-là est une poune!
		Tu as vu ça! Elle poune!	Tu as vu ça! Une poune!
		Yeah! This one is pooning!	*Yeah! This one is a poon!*
		Did you see that? It is pooning!	*Did you see that? A poon!*
EXPERIMENTAL (puppet voice, 20s)	Flower rotating (right) *Vs.* wer jumping (left)	Laquelle poune ?	Laquelle est une poune?
		Montre-moi celle qui poune!	Montre-moi la poune!
		Elle est où, celle qui poune?	Elle est où, la poune?
		(etc..)	(etc…)
		Which one is pooning?	*Which one is a poon?*
		Show me the one that's poonin!	*Show me the poon!*
		It is where, the one that's pooning?	*It is where, the poon?*

presented with two simultaneous pictures of the now-familiar object (the flower). In one, the motion matched that of the familiarization phase (rotating); in the other, the motion was novel (e.g. moving up and down). At that point, the experimenter holding the puppet started to ask questions on-line; she asked the infant to point towards the object/action pair matching the newly-learned verb.

The test phase was 20s long and the experimenter tried to elicit pointing by asking questions throughout this period of time. She always started with the same

two questions ('Which one is pooning? Show me the one that's pooning!), then went on asking variants of these questions, interspersed with 'Please, Tom', and occasionally 'My little eyes cannot see very well!'. She stopped asking as soon as the infant pointed, or at the end of the trial (she knew the trial ended when she heard a baby laugh that separated one trial from the next). All pointing responses were reinforced by thanking the infant, whatever the direction of pointing was ('Thank you, Tom.Thank you very much!'). The rest of the trial was fast-forwarded to avoid a long 'blank' interval for infants who pointed fast. Meanwhile, the puppet filled the silence with praise ('You're such a great help to me, Tom! You show very well! Thank you so much!'). Table 2 shows the complete script for one trial, in French, together with the English glosses (left-hand column). The same sentences were used in all trials (changing only the relevant verb). The contrast and test phases were presented twice (overall: familiarization, contrast 1, test 1, contrast 2, test 2), so that the infants had 8 opportunities to respond to questions by pointing.

If infants correctly mapped the novel verb to the action, they should point more towards the familiar action (flower rotating), than towards the novel one (flower moving up and down). However, infants might also point towards the familiar action for either one of the following wrong reasons: (1) because they mapped the new word to the whole object/action pair; (2) because they have a tendency to perseverate and point towards the most familiar thing in their environment; or (3) because they mapped the new word to the precise object seen during familiarization (like a proper name), and, being faced with 2 identical objects during the test phase, they assumed that the object continued to perform the same action. To test for these alternative interpretations, a control group of infants was run: these infants watched the exact same sequence of events, but were taught a novel noun instead of a novel verb. During familiarization, they heard 'the poon is there!'; during contrast, 'uh-oh, this one is not a poon! Yeah, this one is a poon', and during test, they were asked on-line 'Which one is a poon? Show me the poon!' (see Table 2, right-hand column, for the complete set of sentences used in the control condition). Since the screen showed two instances of the same object performing two different actions, this question is pragmatically inappropriate for adults; the new noun, 'poon', matches both objects. If infants, like adults, interpret the new word as a label for the category of objects, they may either point to both objects, point at chance, or point more often to the novel action (just because it is more interesting)[1]. What they clearly should not do, is point more towards the familiar action. In contrast, if they use

[1]The latter option was more likely according to data collected using the IPL paradigm with the same stimuli, see Lidz, Bunger, Leddon, & Waxman (2006).

any of the strategies outlined above, they should show the exact same behavior as the experimental group, and point more often towards the familiar action.

The order of presentation of items was counterbalanced between participants (four different orders were used in four sub-groups of infants). For each infant, the familiar action appeared on the right side of the screen half the time, and on the left side half the time. The left-right order was quasi-random (with no more than 3 trials in a row with the familiar action on the same side).

Experimental Stimuli

The visual stimuli consisted of 3D objects made using the Amorphium software database. Four different objects and four different actions were used. All actions were rigid movements (that is, the object moved without undergoing any deformations). The following 4 object/action pairs were used: a flower rotating on a horizontal axis, a penguin jumping from left to right while rotating on a horizontal axis, an apple rotating on a vertical axis, and a pot moving up and down. During test, the same object appeared with two actions: its own action (familiar) and a novel one that was one of the other three actions. As a result, each action served once as familiar action and once as novel action (this ensures no bias in the stimuli, if one action for instance was particularly interesting and attracted more points than the others). Two other objects and actions were used for the contrast phases, yielding 4 new object-action combinations, one for each trial: a frog sliding, a frog jumping from left to right, a hippopotamus sliding, and a hippopotamus jumping from left to right.

The acoustic stimuli for the familiarization and contrast phases consisted of child-directed sentences uttered by a female native speaker of French (different from the puppet's voice). Four CVC pseudo-words were used as new verbs and nouns: 'poune' /pun/, 'nuve' /nyv/, 'dase' /daz/ and 'fome' /føm/. All of these respect the phonotactics of French and are perfectly plausible both as nouns and as verbs (3rd person singular present tense; the infinitive forms would be respectively: 'pouner' /pune/, 'nuver' /nyve/, 'daser' /daze/ and 'fomer' /fome/). The full set of the sentences that were used is presented in Table 2 (only the pseudo-words were changed from one trial to the next). As can be seen from the table, the noun and verb sentence frames were as well matched as possible as regards the position of the target word[2]. In addition, they were pronounced with similar intonations, so that the target word received as much stress and emphasis when it occurred as a noun or as a verb. Sentences were recorded using a SONY microphone

[2]The pseudo-noun often came one syllable later than its verb counterpart, due to the insertion of an article, and the negative sentences used during the contrast phase do *not* allow a similar position for nouns and verbs in French.

connected to a PC and were sampled at 16 KHz. Visual and auditory stimuli were combined using Final Cut Pro software into mpeg video clips of 6min 8s, containing 4 complete trials. The clips were run using Quick Time Player, on a Macintosh Power G5 computer.

Data analysis

Infants' behavior was recorded using a Canon MVX10i video camcorder on a digital cassette. A pencil line drawn in the middle of the highchair's tablet facilitated the coding. Coders identified the direction of pointing for each trial, using the following 6 categories: 'left' (clear pointing response towards the left side), 'right' (same for the right side), 'both' (simultaneous pointing response to both sides, using both arms), 'out' (pointing outside the screen, at oneself, mum, the puppet), 'unclear' (a pointing response whose direction was ambiguous), and none (no pointing response during the full 20 seconds of the test trial). Whenever an infant gave more than one pointing response (e.g. pointing left, then right, then left again), then the first response was coded. After coding was finished, all clear pointing responses ('left' and 'right' categories) were then categorized into 'pointing towards the familiar action' and 'pointing towards the novel action'. Twenty-five percent of the infants were double-coded by an independent coder (4 infants in each group), with a good inter-coder reliability (Cohen's Kappa = 0.81).

RESULTS

The mean numbers of clear pointing responses per infant are shown on Figure 1. They were analysed in an ANOVA with the between-subject factor Group (Experimental vs. Control) and the within-subject factor Familiar/Novel (familiar action vs. novel action). The mean number of clear pointing responses was 5.35 (out of 8 possible responses)[3], with no main effect of Group[4] or Familiar/Novel (both $F(1,30) < 1$). Crucially, the interaction between Group and Familiar/Novel was significant ($F(1,30) = 11.2$; $p < 0.01$). Infants in the Experimental group pointed significantly more often towards the Familiar action than to the Novel

[3]In 2.65 cases out of 8, children did not give a clear pointing response: 0.05 responses were 'out', 0.25 responses were 'both' (simultaneous pointing to both sides, using both arms), 0.65 were 'unclear', and for the rest of the trials, 1.7, the infants did not point at all (there were no significant differences between the Experimental and the Control groups on any of these variables).

[4]The absence of a main effect of Group indicates that children pointed equally often whether they were taught a new verb or a new noun. It might have been the case that infants in the Control group pointed less often, since they were asked a puzzling question. But they did not.

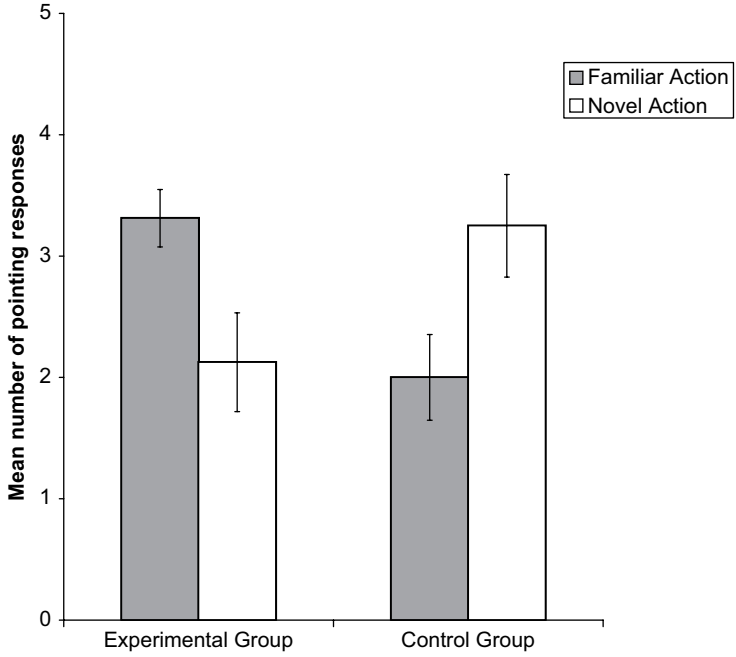

FIGURE 1 Number of pointing responses towards the familiar and unfamiliar actions for infants in the Experimental and Control groups. Error bars represent standard errors of the means.

one (3.3 vs. 2.1, $F(1,15) = 6.7$; $p < 0.02$). In contrast, infants in the Control group pointed significantly more towards the Novel action than to the Familiar one (3.3 vs. 2.0, $F(1,15) = 4.8$; $p < 0.05$)[5]. 325

Thus, infants in the Experimental group, who were taught a new verb, pointed more often towards the correct answer, the familiar action, in contrast to infants in the Control Group, who were taught a new noun and showed a novelty preference. The significant difference in behavior between the two groups of infants can only be due to the difference in the sentence frames in which they heard the 330 novel word (novel verb vs. novel noun).

[5]Another way to look at these data is to compute the percentage of points towards the familiar action, for each infant (number of points towards familiar action, divided by total number of clear pointing responses for that infant). This percentage analysis gives the same results, with a significant preference for the familiar action in the Experimental Group (65.9%, significantly greater than chance, 50%, $t(15) = 3.2$, $p < 0.01$); and a significant preference for the novel action in the Control Group (35.5% points towards the familiar action, significantly smaller than 50%, $t(15) = -2.1$, $p < 0.05$), and the behaviour of the two groups was significantly different: $t(31) = 3.6$, $p < 0.001$.

DISCUSSION

Our aim was to evaluate whether children could use syntactic context to infer that a word is a verb, and thus refers to an action. In this study, infants were taught novel words while looking at an object performing an action. Results showed that when infants heard novel verbs presented in very short sentences, they selectively associated them to actions. Indeed, when given a choice between the same object performing either the familiar or a novel action, and being asked to point towards "the one that's pooning" (if 'poon' was the novel verb), they reliably pointed towards the object performing the familiar action. To ascertain that infants were not simply perseverating at pointing at the picture they had already seen, infants in the control group were taught novel nouns on the same visual stimuli. In stark contrast to verb-learning infants, noun-learning infants pointed more often to the object performing the new action when asked to point to "the poon" (if 'poon' was the novel noun). This behavior can be considered as a classical novelty preference as observed in looking experiments (see Bernal, Lidz, Waxman, Dutat, & Christophe, 2005). A bias to point to the novel action may also arise because infants typically point to attract their parents' attention to novel things in their environment (deictic pointing). Importantly, infants in the Experimental Group managed to overcome their novelty preference in order to provide the correct answer to the question they were asked. The difference in behavior between infants from the experimental and the control group shows that 23-month-old infants can exploit the syntactic context of a word online and use it to infer some of its semantic properties.

In this study, infants could only have inferred the word category by using its co-occurring function words. Mintz (2003) has recently suggested that syntactic categorization might arise from the use of "frequent frames" (i.e. pairs of words that co-occur frequently with one word between them). For instance, in English, the frame [the _ is] allows the algorithm to spot nouns (as in 'the dog is', 'the car is', etc); while [I _ it] frames exclusively verbs (as in 'I see it', 'I put it'). This work has recently been replicated in French (Chemla, Mintz, Bernal, & Christophe, in press), in which frames such as [ne _ pas] pick out verbs, while [le _ de] picks out nouns. Some of the sentences we used during familiarization featured some of the most frequent frames of French (such as [ne _ pas] for verbs, [le _ est] for nouns). The simple co-occurrence of the preceding function word with the new content word can also give some information about its category. German infants have recently been shown to use a preceding article to categorize nouns (Höhle, Weissenborn, Kiefer, Schulz, & Schmitz, 2004).

The ability to use function words as categorizers may arise quite early in development. Infants distinguish function and content words since the first months of life (Shi & Werker, 2001; Shi, Werker, & Morgan, 1999) and use them as a cue to segment continuous speech (Shi & Gauthier, 2005). Toddlers also understand sentences better when they contain real function words than when

these are replaced by nonsense or misplaced functors (Gerken, 1994; Gerken & McIntosh, 1993; Kedar, Casasola, & Lust, 2006; Shipley, Smith, & Gleitman, 1969; Zangl & Fernald, in press). Our work shows that 2-year-olds can use function words to categorize novel content words and infer their probable meaning. These results differ from Brown (1957) in two ways. First, in our materials the only information about the syntactic category of the novel word was carried by the co-occurring function words. In Brown's study, both function words and inflectional morphology were available to distinguish words from different grammatical categories. Second, the participants in our study were considerably younger than the preschoolers tested in Brown's seminal work.

The fact that our participants were able to infer the meaning of a novel verb on the basis of co-occurring function words raises the question of how infants come to determine which function words are attached to which category of content words. One possibility is that infants first group words together by using some kind of distributional strategy (such as the 'frequent frames' mentioned above). This done, they could 'label'[6] whole categories as 'nouns' or 'verbs' by identifying the category of just a few nouns and verbs amongst them. One way to do this would be to guess the meaning of a few very frequent words referring to concrete objects and events (see also Chemla, Mintz, Bernal, & Christophe, in press). In real life, infants probably combine different strategies to acquire novel words depending on the situation. For example, Tomasello and Akhtar (Tomasello & Akhtar, 1995) presented novel words to 27-month-olds without any linguistic context but within a meaningful socio-pragmatic context. In that case, infants were able to link the novel word either to the action or to the object by relying on the pragmatics of the situation (novel object or novel action). Further work is needed to understand better how the child combines different strategies in word learning and what their developmental trajectories are.

Moreover, our experiment widens the scope of the syntactic bootstrapping hypothesis as a linguistic strategy for lexical acquisition. The present research shows that infants can use syntax to infer the meaning of different categories of words (nouns vs. verbs) and not only of transitive vs. intransitive verbs (Fisher, 2002; Naigles, 1990; Naigles & Kako, 1993). Recently, some studies have also shown that different sentential contexts (noun vs. adjective) change 14 month-old expectations about the meaning of a word (Booth & Waxman, 2003). Fisher, Klingler, & Song (2006) have also suggested that children can use argument structure, in that case the presence of a noun phrase, to decide whether a word should be considered as a preposition or a noun ("this is *acorp* my box", *acorp* = preposition vs. "this is a *corp*", *a corp* = NP), and hence whether its meaning is relational. In our experiment, there

[6]By labelling, we mean the ability to generalize the properties of one of the members of the category to the others. We do not assume that children have conscious access to abstract categories such as nouns and verbs.

were no content words, so that only function words could be relied on to compute the argument structure. All these experiments point to the conclusion that syntactic structure is crucial for word categorization and lexical acquisition.

Finally, we would like to say a few words about the use of a pointing response (see also Casenhiser & Goldberg, 2005; Fernandes, Marcus, DiNubila, & Vouloumanos, 2006; Fisher, 2002). Before running this experiment, we tried to use the IPL paradigm (using essentially the design of Waxman & Booth, 2003) to test our hypothesis with similar materials at the same age: the looking data we obtained was extremely noisy (Bernal, Lidz, Waxman, Dutat, & Christophe, 2005). In these studies, a few infants spontaneously pointed towards the correct answer. However, as soon as they had responded, their gaze switched back and forth between the left and right image, giving rise to very noisy looking data. In the present experiment, pointing proved to be a reliable methodology, in which infants were keen to engage. Deictic pointing responses had already been observed in experimental conditions in 12 month-olds (Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004) and we built on this ability to train the children to answer questions by pointing.

To conclude, this work shows the ability of French 23-month-olds to use the syntactic context in which a novel word occurs to infer its meaning. It emphasises the crucial role of function words in the lexical categorization of nouns and verbs. This makes sense since infants start having some knowledge of function words early in development, possibly towards the end of the first year of life.

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