Syntax constrains the acquisition of verb meaning

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Abstract:

Can infants use the syntactic context of an unknown word to infer that it is a verb, and thus refers to an action? 23-month-old French infants watching a moving object were taught novel verbs, within sentences that contained only function words (“il pousse 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 (“un poule est là”/ “a poon is here”). Contrary to verb-learning infants, noun-learning infants 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 colour 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 e.g. 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). Thus, some basic knowledge about syntax may help the children access the meaning of novel words. This hypothesis has received support from adult experiments (Gillette, Gleitman, Gleitman, & Lederer, 1999), as well as from toddlers (Fisher, Hall, Rakovitz, & Gleitman, 1994; Lidz, Gleitman, & Gleitman, 2003) and infants (Fisher, 2002; Naigles & Kako, 1993; Waxman & Booth, 2001).

In the present study, we investigated a very simplified version of the syntactic bootstrapping hypothesis, namely that the syntactic category of a word may cue its meaning. For example, nouns generally refer to object categories, while verbs typically refer to event categories and adjectives to properties of objects (Grimshaw, 1981; Macnamara, 1982; Maratsos & Chalkley, 1980; Pinker, 1987). But how can a child access 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 (Shafer, Shucard, Shucard, & Gerken, 1998; Shi, Werker, & Morgan,
1999) 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 categorization (Höhle, Weissenborn, Kiefer, Schulz, & Schmitz, 2004). 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, submitted; Mintz, 2003; Mintz, Newport, & Bever,
2002).

In this study, we asked whether infants would attribute a different meaning to a novel
word depending on the syntactic context in which it occurred. We defined this context by
varying the functional elements co-occurring with the word. In particular, we supposed that a
novel word presented as a verb (i.e. co-occurring with pronouns for instance) would be taken
to refer to an action. 23-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 looking paradigm,
together with a novel response: pointing.
Material and Method

Subjects

32 children from monolingual French-speaking homes participated in this experiment (18 girls, mean age 23:02 months, range 22:18 to 23:15). They had no known neurological or hearing deficit. 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 Mac Arthur CDI test (Kern, submitted). The results from 35 additional subjects were not analyzed for the following reasons: not pointing during introduction (9), not pointing during training (12), crying/fussing/not completing the experiment (9), mother speaking (1), technical problem (2), experimenter error (2).

Design

Set up: Infants were seated in a high-chair, facing the screen on which the stimuli were projected. Parents were seated behind the infants and were instructed not to talk to or distract infants. They wore headphones displaying masking noise. Sessions lasted approximately 15 min and were videotaped for later coding.

Procedure: Since our aim was to get the infants to answer a question by pointing, they were first exposed to an introduction and a training session, then to the experimental session.

During the Introduction, the infant was seated in front of a table. Two cardboard boxes were placed on the table, their opening facing the infant. First, the infant was introduced to a puppet and four animal toys (a dog, a cat, a hen and a giraffe, words known to children of this age). The puppet sat on the opposite side of the table and was operated by an experimenter kneeling behind the table so that her face and shoulders were visible. The puppet announced a hide-and-seek game and hid under the table. The experimenter, speaking in her normal voice,
chose two of the toys, named them and put them in each of the two boxes while commenting her actions (“Look, this is the dog! The dog is going in that box! Do you see the dog here?” “Oh, and this is the cat!” etc.). The experimenter then made the puppet come back and ask for one of the animals (“I am looking for my friend the dog. Can you help me find the dog? I can’t see him! Can you show me where the dog is hiding, please?” etc.). The experimenter controlling the puppet asked different questions until she managed to elicit a pointing response from the infant. If the infant pointed towards the right animal, the puppet would thank her profusely, give her 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), she was allowed to continue with the training session. If not, she was excluded from the study.

The Training session was aimed both at familiarizing the infant to play the game on the screen and at teaching her to point towards an action. Three short sequences displaying a woman performing familiar actions (eating, drinking and giving) were shown to the infant while the puppet labeled the actions. Then the pointing game resumed. Two pictures of the same toys used during introduction were shown simultaneously on either side of a screen facing the infant. The puppet asked the child to show her one of the animals (“Can you show me the dog, please?”). If the child complied 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?”). When the child had pointed correctly towards three actions, the experiment per se began.

During the Experimental session, infants were randomly assigned to two conditions varying only by the linguistic information provided. One group was presented with control
sentences featuring novel nouns (“Control” condition) and the other group was presented with
sentences featuring novel verbs (“Verb” condition).

For both groups, each trial included three distinct phases, familiarization, contrast and
test (see Table 1, 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). During the Contrast phase, a different object was
presented doing a different action (e.g. a frog sliding) followed by the first object doing the
familiar action. In the Test phase, infants were 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. bouncing). After each familiarization
phase, the contrast and test phases were presented twice (familiarization, contrast, test 1,
contrast, test 2).

During Familiarization and Contrast, infants in the Control condition heard a novel
noun, e.g., “La poune est là!” (The poon is there), while those in the Verb condition heard a
novel verb, e.g., “Elle poune par là” (It is pooning there). During Test, infants were asked a
question online by the puppet. The experimenter holding the puppet was sitting on the side of
the table, her back to the screen. She did not know which side corresponded to the familiar
action. Infants in the Control condition were asked a question featuring the now familiar
noun, e.g. “Tu peux me montrer la poune?” (Can you show me the poon?). In the Verb
condition, the familiar verb was presented, e.g. “Tu peux me montrer celle qui poune?” (Can
you show me the one that’s pooning?). The test phase was 20s long and the experimenter tried
to elicit pointing by asking questions throughout this period of time. She stopped asking as
soon as the child had pointed or at the end of the trial. All pointing responses were reinforced
by thanking the infant whatever the direction of pointing was.
If infants in the Verb condition correctly mapped the novel verb to the action, they should point more towards the familiar action (e.g. flower rotating), i.e. the “correct” answer, than towards the novel one (e.g. flower bouncing). Infants in the Control group, however, were asked a puzzling question for which both sides of the screen provided a correct answer (e.g. flowers on each side). We thus expected infants in the Control group either to point at chance or to show a novelty preference, and point more towards the novel action.

**Experimental Stimuli**

Order of presentation of items and position of the target action (left or right) were counterbalanced between participants. Each infant learned four novel words (associated with four different objects/actions), and was tested twice for each of them, thus leading to a total of 8 test trials altogether. See Table1 for an example of the sentences and video stimuli used in each phase of the experiment, and in each condition.

The acoustic stimuli for the familiarization and contrast phases consisted of child-directed speech sentences uttered by a female native speaker of French (different from the puppet’s voice, see Table1). Sentences were recorded using a SONY microphone connected to a PC and were sampled at 16 KHz. The visual stimuli consisted of 3D animated objects made using the Amorphium software database. Four different objects (flower, penguin, apple, pot) and four different actions (jumping, sliding, rotating vertically, rotating horizontally) were used for familiarization and test trials. Another two objects and actions were used for the contrast phases. Visual and auditory stimuli were combined using Final Cut Pro software into mpeg video clips of 6min8s, containing 8 trials. The clips were run using Quick Time Player.

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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).
Stimuli were presented on a screen (1.5m * 2m) using a video-projector and loudspeakers connected to a Macintosh Power G5 Computer.

Data analysis:

Children's behavior was recorded using a Canon MVX10i video camcorder on a digital cassette. Films were then exported through iMovie. The videotaped sessions were transcribed with the sound removed to ensure that the coders were blind to condition assignment. Coders identified each infant’s direction of first pointing for each trial (left, right, both, out).

For each child, we computed the number of pointing responses towards each stimulus (familiar action, novel action, unclear) and the total number of pointing responses. We then computed ANOVAs with Condition (Familiar, Novel) as a within subject factor and Group (Verb, Control) as a between subject factor.

Results:

Both groups scored similarly on the CDI questionnaire (Verb group, 223.6, Control Group, 225, t(31)=1.13, p=0.27). The mean number of pointing responses was 5.9 (amongst 8 possible trials)\(^2\), with no main effect of Group or Condition. Crucially, the interaction between Group and Condition was significant (F(1,30) =12.3; p<0.002). Infants in the Verb group pointed significantly more often towards the familiar action than to the unfamiliar one (3.2 vs 1.9, F(1,15)=7.4; p<0.02). In contrast, infants in the Control group pointed significantly more towards the unfamiliar action than to the familiar one (3.3 vs 2.0, F(1,15)=5.3; p<0.05).

\(^2\) Of these, children gave approximately 6.9 % of undirected responses (pointing “out” of the screen) and 5.3% of double responses (pointing at both sides of the screen simultaneously) with no significant difference between the two groups.
Thus, infants in the Verb group pointed more towards the correct answer (familiar action) whereas infants in the Control Group, when given the choice between both pictures as correct answers, showed a novelty preference. The significant difference in behavior between the two groups of infants can only be due to the difference in linguistic contexts (novel verb vs novel noun).

Discussion:

Our aim was to evaluate whether children could use the 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 behaviour can be considered as a classical novelty preference as observed in looking experiments (see Bernal, Christophe, Waxman, & Lidz, 2005). Alternatively, a bias to point to the novel action may arise because infants typically point to attract their parents’ attention.
to novel things in their environment (deictic pointing). The comparison between the verb group and the control group suggests that 23-month-old infants can access the syntactic category of a word online and use it to infer some of its semantic properties.

In this study, infants could only infer the word category by using its co-occurring function words. Mintz (2003) has recently suggested that categorisation might arise from the use of “frequent frames” i.e. pairs of words that occur frequently with one word between them. This work has recently been replicated in French (Chemla et al., submitted). In our stimuli, two frequent frames of French were present, one for verbs (“ne_pas”) and one for nouns (“le/la_est”). Infants’ learning may have relied only on these specific frames or may have taken advantage of the variability of contexts used in familiarization (negations, variety of pronouns etc.). 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 et al., 2004).

The ability to use function words as categorizers may arise along development. Infants distinguish function and content words since the first months of life (Shi & Werker, 2001; Shi et al., 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 et al., 2006; Shipley, Smith, & Gleitman, 1969; Zangl & Fernald, 2005). Our work shows that 2-year-olds can use function words to categorize novel content words and infer their probable meaning.

However, it does not explain how infants assessed what function words are attached to which category of content words. One possibility is that they acquire the meaning of some content words given a meaningful context and thereby determine which syntactic category is
associated to which function words (as in Pinker, 1984). They could then generalize this knowledge to novel words. In real situations, infants probably combine different strategies to acquire novel words depending on the situation. For example, Tomasello and Akhtar (1995) have 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 expectancies 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 \textit{acorp my box}”, \textit{acorp} = preposition vs. “this is a \textit{corp}”, \textit{a corp} = NP). In our experiment, there were no content words, so that only function words could be relied on to compute the argument structure. Even in that extreme case, syntactic structure is crucial for word categorization and lexical acquisition.

Finally, it is important to note that these results were obtained using a novel methodology. We first tried to use the IPL paradigm (as used by Waxman & Booth, 2003) to test our hypothesis with similar materials at the same age, and obtained extremely noisy looking time data (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.
**Authors’ Note**

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**Fig. 1**: Number of pointing responses towards the familiar and unfamiliar actions for infants in the Verb and Control groups. Error bars represent standard errors.
<table>
<thead>
<tr>
<th>Phase</th>
<th>Video</th>
<th>Verb Condition</th>
<th>Noun Condition</th>
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| **FAMILIARIZATION** (off voice, 20s) | Flower rotating (left) | Regarde, elle poune !
Tu as vu ? Elle poune !

*Look! It’s pooning!*

*Do you see? It’s pooning!* | Regarde, c’est une poune
Tu as vu ? Une poune !

*Look! This is a poon!*

*Do you see? A poon!* |
|                    | Flower rotating (right)   | Regarde maintenant !
Elle poune par là !
Tu vois comment elle poune ?

*Now look! It’s pooning there!*

*Do you see how it’s pooning?* | Regarde maintenant !
La poune est là !
Tu vois ce que fait la poune ?

*Now look! The poon is there!*

*Do you see what the poon is doing?* |
|                    | Flower rotating (left)   | Oh, elle poune encore là !
Tu la vois qui poune ?

*Oh! It’s pooning there again!*

*Can you see it pooning?* | Oh, la poune est encore là !
Tu la vois cette poune ?

*Oh! The poon is there again!*

*Can you see this poon?* |
| **CONTRAST** (off voice, 10s) | Frog sliding (center)   | Oh oh, celle-là ne poune pas !
Ceci ne poune pas.

*Uh-Oh! That one is not pooning.*

*This is not pooning.* | Oh oh, celle-là n’est pas une poune !
Ceci n’est pas une poune.

*Uh-Oh! That one is not a poon.*

*This is not a poon.* |
|                    | Flower rotating (center) | Oui! Celle-là poune !
Tu as vu ça ! Elle poune !

*Yeah! This one is pooning!*

*Did you see that? It is pooning!* | Oui! Celle-là est une poune !
Tu as vu ça ! Une poune !

*Yeah! This one is a poon!*

*Did you see that? A poon!* |
| **EXPERIMENTAL** (puppet voice, 20s) | Flower rotating (right) Vs. Flower jumping (left) | Montre-moi celle qui poune.
Tu vois celle qui poune ?

*Show me the one that’s pooning.*

*Can you see the one pooning?* | Montre-moi la poune.
Tu vois la poune ?

*Show me the poon.*

*Can you see the poon?* |

**Table 1:** Example of trials for each condition. Both conditions were closely matched for the position of the target word and the length of the sentences used in familiarization. NB: in French the word is exactly the same in both conditions (no verb marking). A second contrast phase and a second test phase followed.


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