Received: 23 November 2020 | Revised: 6 January 2021 | Accepted: 19 January 2021

DOI: 10.1111/desc.13085

Developmental Science WILEY

PAPER

"*Look! It is not a bamoule!*": 18- and 24-month-olds can use negative sentences to constrain their interpretation of novel word meanings

Alex de Carvalho[1] | Cécile Crimon[2] | Axel Barrault[2] | John Trueswell[4] | Anne Christophe[2,3]

[1]Laboratoire de Psychologie du Développement et de l'Éducation de l'Enfant – LaPsyDÉ, La Sorbonne, Université de Paris, CNRS, Paris, France

[2]Laboratoire de Sciences Cognitives et Psycholinguistique, DEC-ENS/EHESS/CNRS, Ecole Normale Supérieure – PSL University, Paris, France

[3]Maternité Port-Royal, AP-HP, Université de Paris, Paris, France

[4]Department of Psychology, University of Pennsylvania, Philadelphia, PA, USA

Correspondence
Alex de Carvalho, La Sorbonne, 46 rue Saint-Jacques (escalier A, 4ème étage), 75005 Paris, France.
Email: alex.de-carvalho@u-paris.fr

Funding information
This research was supported by a Fyssen Foundation Research Grant award to Alex de Carvalho (grant Eotp RH03J20AFO04_EDENFCOGN°H03R8240). It was also supported by grants from the National Institute of Child Health and Human Development (grant R01HD37507) and the ANR (ANR-17-EURE-0017 FrontCog, ANR-13-APPR-0012 LangLearn, ANR-17-CE28-0007-01 LangAge).

Abstract

Two word-learning experiments were conducted to investigate the understanding of negative sentences in 18- and 24-month-old children. In Experiment 1, after learning that *bamoule* means "penguin" and *pirdaling* means "cartwheeling," 18-month-olds (n = 48) increased their looking times when listening to negative sentences rendered false by their visual context ("*Look! It is not a bamoule!*" while watching a video showing a penguin cartwheeling); however, they did not change their looking behavior when negative sentences were rendered true by their context ("*Look! It is not pirdaling!*" while watching a penguin spinning). In Experiment 2, 24-month-olds (n = 48) were first exposed to a teaching phase in which they saw a new cartoon character on a television (e.g., a blue monster). Participants in the affirmative condition listened to sentences like "*It's a bamoule!*" and participants in the negative condition listened to sentences like "*It's not a bamoule!*." At test, all participants were asked to find *the bamoule* while viewing two images: the familiar character from the teaching phase versus a novel character (e.g., a red monster). Results showed that participants in the affirmative condition looked more to the familiar character (i.e., they learned the familiar character *was* a bamoule) than participants in the negative condition. Together, these studies provide the first evidence for the understanding of negative sentences during the second year of life. The ability to understand negative sentences so early might support language acquisition, providing infants with a tool to constrain the space of possibilities for word meanings.

KEYWORDS
early acquisition of negation, infant development, language acquisition, lexical development, negation understanding, word learning

1 | INTRODUCTION

Negation, a universal linguistic concept, presents a challenging question in language acquisition. Although infants produce the word "no" from 13 months onwards, research has failed to find any understanding of negative sentences before 27 months, and has even observed that toddlers process negative sentences as affirmatives (Austin et al., 2014; Feiman et al., 2017, with 20-month-olds; Nordmeyer & Frank, 2014, with 2- to 3-year-olds). This inability to interpret negative sentences correctly, at an age when children are using sentential context

for vocabulary learning, could disrupt their acquisition of word meanings. For instance, if toddlers assign the same interpretation to sentences such as "This is a *dax*" and "This is not a *dax*," they could make incorrect associations between words and their meanings.

Decades of research demonstrate that well before their second birthday, infants exploit the sentential context in which novel words occur to help discover their meanings (a mechanism called *syntactic bootstrapping*, e.g., Fisher et al., 1994; Gleitman et al., 2005; Landau & Gleitman, 1985; Naigles, 1990). For instance, 14-month-olds learn that a novel word presented as a count noun (e.g., "this one is a *fop*") refers to individual objects and categories of objects (e.g., *a horse*), but not if it is presented as an adjective (e.g., "this one is *fopish*"; Waxman, 1999). Around 18 months, infants learn that a novel word presented as a noun (e.g., "It is a *bamoule*") refers to a novel object, but if presented as a verb (e.g., "It's *bamouling*"), it refers to a novel action (e.g., de Carvalho et al., 2019; He & Lidz, 2017; Oshima-Takane et al., 2011). Infants also use sentential context to infer what type of event a novel verb describes. For instance, 15- to 24-month-olds learn that "*blicking*" refers to a causal action between two participants when they hear transitive sentences (e.g., "Jane is *blicking* the baby"), but not intransitive sentences (e.g., "Jane is *blicking*"; e.g., Arunachalam et al., 2013; Dautriche, et. al., 2014; de Carvalho, et al., 2021; Fisher et al., 2020; Jin & Fisher, 2014; Messenger et al., 2015, Suzuki & Kobayashi, 2017; Yuan et al., 2009, 2012). Furthermore, 19-month-olds can exploit the semantic and syntactic context together, and infer that "*dax*" refers to an animate entity (e.g., a novel animal, rather than an inanimate object) when they hear "The *dax* is crying" in which "dax" appears in the subject position of a familiar verb requiring an animate agent (Ferguson et al., 2014; Ferguson et al., 2018; see also Syrett et al., 2019).

Together, these studies demonstrate that well before age 2, infants use the syntactic/semantic context of sentences to make inferences about word meanings. What remains unknown, however, is whether this mechanism would still work if infants need to integrate the meaning of negative elements when making their inferences. When infants are exposed to negative sentences like "This is not a *bamoule*," "The *dax* is not crying," "She is not *blicking* the baby," do they make any inference about the meaning of novel words? If children rely on the sentential context of words to identify their potential referents (as proposed by the *syntactic bootstrapping* hypothesis), it is important for them to correctly integrate the information carried by negation in their interpretation of sentences. They need to be able to distinguish between affirmative ("This is a bamoule") and negative sentences ("This is *not* a bamoule") and to exploit the syntactic context of negative sentences, as well as they do for affirmative sentences, to constrain their interpretation of word meanings. These are the issues investigated in the current study.

As opposed to an affirmative sentence like "this is a cat," from which infants could associate the word "cat" to a given referent, a negative sentence like "this is not a cat" makes the associations between words and their meanings more complex. The sentence "this is not a cat" communicates that the referent is not a member of the semantic category cat, and thus for a child who does not know the meaning of the word *cat*, it provides only exclusionary semantic information about word meaning. The two questions of interest here are how young children interpret negative sentences during the first steps of language acquisition and how they use these resulting interpretations to inform their hypotheses about word meanings.

Research highlights

- Across two studies testing different aspects of the processing of negative sentences, we observed that 18- and 24-month-olds are able to understand negative sentences.
- Although previous studies suggested that children younger than 2 process negative sentences as affirmatives, here we report opposite behaviors for the two types of sentences.
- This is the first study showing that infants understand negative sentences and can potentially use this information to constrain their interpretation of word meanings.
- This ability to understand negative sentences so early might support language acquisition, providing infants with a tool to understand the boundaries of a word's meaning.

Several studies have investigated the acquisition of negation by examining *how* and *when* children start producing negative sentences (Bloom, 1970; Cameron-Faulkner et al., 2007; Choi, 1988; Drozd, 1995; Guidetti, 2005; Hummer et al., 1993; McNeill & McNeill, 1967; Pea, 1980; Tam & Stokes, 2001; Vaidyanathan, 1991). These studies found that as early as 13 months, infants start producing the word "no" (or "non" in French) and that from about 13 to 24 months, they begin producing negative sentences to express refusal (e.g., "Veux pas"—"Don't want!"), nonexistence (e.g., "Il y a plus de lumière"—"No more light!" just after the light is turned off), and around age 2, they begin producing even more complex negative sentences expressing denial (e.g., "Not a cat!" when they are in front of a *dog* and answer someone who asked them if the animal was a cat; see, e.g., Choi, 1988, for a cross-linguistic longitudinal study of negation in English, French, and Korean). Parents' production of negation in child-directed speech has also been investigated (e.g., Cameron-Faulkner et al., 2007; Jasbi et al., 2020) and the results show that the two most frequent functions of negation words were *prohibition* and *denial*, and that the negative elements used frequently in the input were the first to emerge in the child's speech (e.g., no-not-'nt).

Surprisingly, however, the few existing experimental studies investigating the comprehension of negative sentences in children have found that 20-month-olds incorrectly interpret them as affirmatives (a fact replicated in different labs: Austin et al., 2014; Feiman et al., 2017) and that even 2- to 5-year-olds have difficulty understanding negative sentences in some tasks (Austin et al., 2014; Doyle et al., 2019; Feiman et al., 2017; Grigoroglou et al., 2019; Kim, 1985; Nordmeyer & Frank, 2014; Pozzan et al., 2019; Reuter et al., 2018).

For instance, in Austin et al. (2014) and in Feiman et al. (2017), children from three age groups (20-, 24-, and 27-month-olds) participated in an experiment in which they had to find an object that was hidden by a first experimenter either in *a bucket* or *a house*; a second experimenter (or the participant's caregiver in Feiman et al., 2017) asked questions to the first experimenter, such as "Is it in this *house?*" or "Is it in this *bucket?*". The first experimenter replied either with an affirmative sentence: "It is in this house," or with a negative sentence: "It's not in this bucket." Participants were then asked to find the hidden object. While the 27-month-olds found the hidden object in the correct place after listening to each type of sentence in both studies, 24-month-olds did not: in Austin et al., 24-month-olds searched in the correct place only in response to negative sentences, while in Feiman et al., 24-month-olds succeeded with affirmatives but performed at chance with negative sentences. The youngest group, in both studies, did not distinguish between affirmative and negative sentences, and interpreted negative sentences as if they were affirmatives: when they listened to "Yes! It is in the *bucket*" or "No! It is not in the *bucket*!", they searched for the hidden object in "the bucket."

The failure of 20-month-olds and the conflicting results for 24-month-olds, can be interpreted in two ways. First, it is possible that before 27 months, children simply do not yet understand negative sentences, a purely linguistic difficulty. If this hypothesis is correct, children's early production of negation would reflect the fact that they have only a basic meaning for the words "no" and "not" (e.g., to express rejection), but they cannot yet compute the meaning of sentences containing more complex types of negation (e.g., sentences expressing denial or nonexistence). This situation might pose a problem for language acquisition, because if infants assign the same interpretation to affirmative and negative sentences, they risk making incorrect associations between words and their referents. A second hypothesis for why younger children failed to demonstrate understanding of negative sentences is that they lacked some skills that were necessary to succeed in the tasks. When children heard negative sentences in the experiments described above, they had to inhibit their first action, which was to turn their attention toward the named container (e.g., *the bucket*, which does not contain the object in the case of negative sentences), in order to successfully search for the hidden object in the other "non-named" container (e.g., *the house*). Switching responses introduces conflict demands that are difficult for young children even in non-linguistic tasks (Cepeda & Munakata, 2007; Diamond, 2013). In this case, toddlers' correct understanding of negative sentences might be revealed in a task that does not require them to process a negative sentence while simultaneously choosing between two alternatives.

Here we explored this possibility by investigating infants' understanding of negative sentences in word-learning situations with fewer processing demands. Experiment 1 used a simple habituation/dishabituation task to test whether 18-month-olds can understand negative sentences and distinguish between affirmative and negative sentences. In Experiment 2, we directly compared how 24-month-olds exploit affirmative and negative sentences to inform their interpretation of novel word meanings.

2 | EXPERIMENT 1

To test whether 18-month-olds understand negative sentences, we exploited a paradigm recently used in English and French, showing that 18-month-olds, upon hearing sentences such as "Look, It's a *bamoule*!" infer that *bamoule* refers to an object, while from sentences such as "Look! It's *pirdaling*!" they infer that *pirdaling* refers to an action (de Carvalho et al., 2019; He & Lidz, 2017). In those studies, 18-month-olds were habituated with two video stimuli showing a penguin performing two different actions (spinning and cartwheeling), one in each video. During the presentation of one of the videos (e.g., a penguin spinning), participants heard sentences using the novel word as a noun (e.g., "Oh Look! It is a *bamoule*!" where *bamoule* was referring to the object in the video: the penguin), while during the presentation of the other video (e.g., a penguin cartwheeling), participants heard sentences using a novel word as a verb (e.g., "Oh Look! It's *pirdaling*!" where *pirdaling* was naming the action being performed: cartwheeling). Immediately after this habituation phase, infants were exposed to a test in which the associations between the sentences and the videos were switched: the noun sentences were presented with the video previously associated with the verb (e.g., cartwheeling; the Noun-Switch condition) and the verb sentences were presented with the video previously associated with the noun (e.g., spinning; the Verb-Switch condition). The results showed that when participants heard the noun sentences "It is a *bamoule*" while watching the penguin cartwheeling, they did not increase their looking time to the video because there was still a penguin in the video (although it was "cartwheeling" instead of "spinning"). However, when participants heard the verb sentences "It's *pirdaling*" while watching the penguin *spinning* instead of *cartwheeling*, they looked longer at the video, because this kind of switch violated the inference they had constructed about the verb meaning during the habituation phase (i.e., "cartwheeling" and "spinning" are different actions).

The current study implemented a slight modification in this experimental design (as summarized in Figure 1) such that negative sentences were presented during the test phase: one negating the verb meaning learned during the habituation phase, and the other one negating the noun meaning. Thus, after the same habituation phase where children learn that *bamoule* refers to "penguin" and *pirdaling* to "cartwheeling," in the test phase, upon hearing negative sentences like "Oh look! It is *not pirdaling!*" while watching the penguin spinning (the Negative Verb-Switch condition) infants should not look significantly longer to the video, because indeed the penguin is not *cartwheeling* anymore, but *spinning*. In contrast, upon hearing sentences such as "Oh look! It is *not a bamoule!*" while watching the penguin cartwheeling (the Negative Noun-Switch condition), they should look longer to the video, because there is still a penguin in the video and the sentence is false. In other words, if infants integrate the information carried by the negative elements to constrain their interpretations, we expect that in the test phase, where only the actions changed, but the penguin is still the same, they should look longer at the video in the Negative Noun-Switch than in the Negative Verb-Switch condition[1].

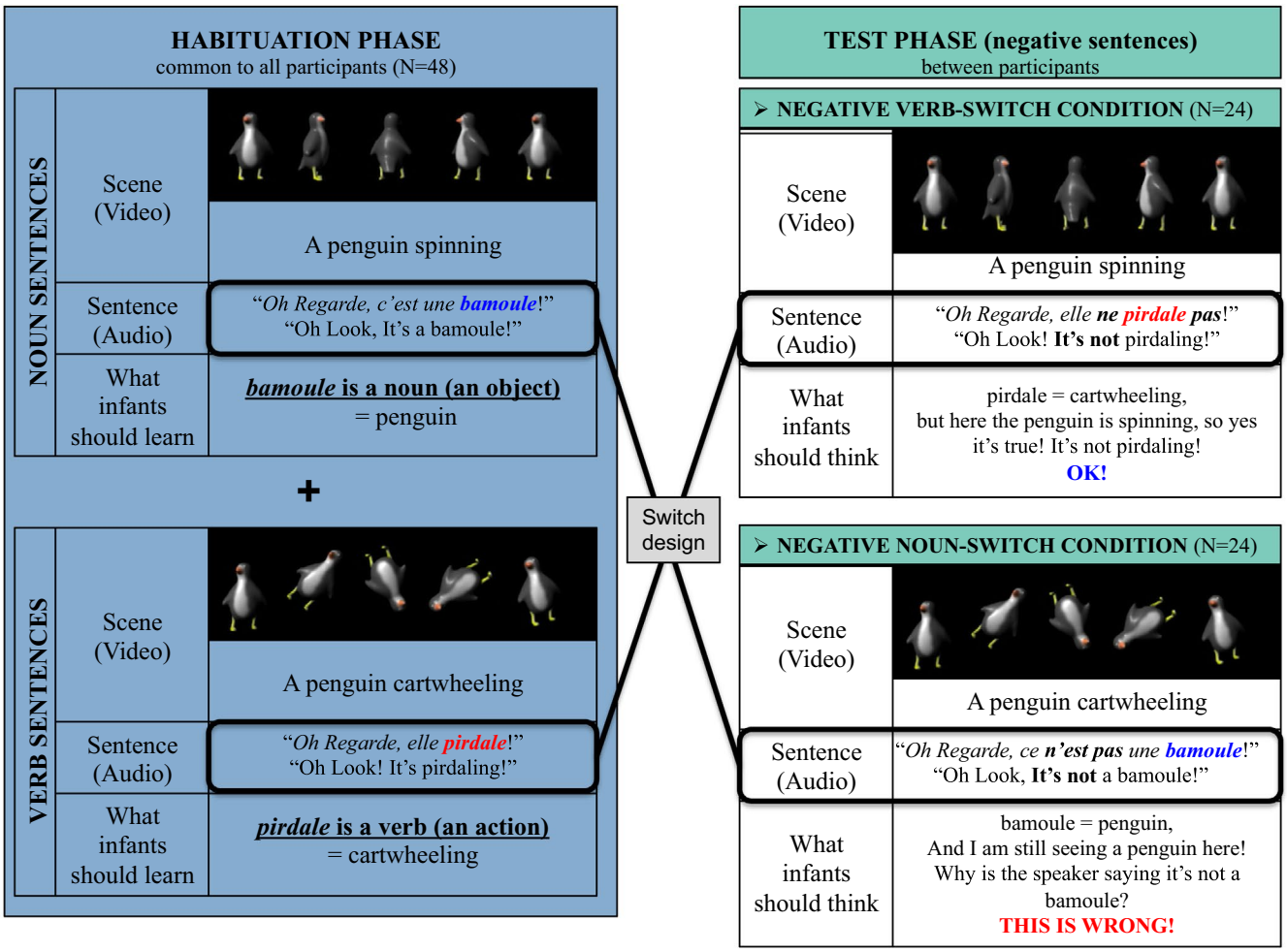

FIGURE 1 Experimental design (Habituation—Switch design, e.g., de Carvalho et al., 2019; He & Lidz, 2017; Werker et al., 1998). All infants (*N* = 48) were habituated with the same two video stimuli. These two videos showed either a penguin doing a spinning action or a penguin doing a cartwheeling action. While watching one of the videos (e.g., spinning) infants listened to sentences in the noun condition, and while watching the other video (e.g., cartwheeling), they listened to sentences in the verb condition. At test, all infants heard negative sentences introducing a switch between the videos and the sentences they heard before, such that half of the infants (*N* = 24) heard negative sentences in the Negative Noun-Switch-condition and half heard negative sentences in the Negative Verb-Switch condition. Given that during the habituation phase, the noun always referred to the penguin, while the verb referred to an action (e.g., cartwheeling), if infants correctly understand negative sentences, they should look more toward the video, in the Noun-Switch-condition (because the speaker says that the penguin is not a *bamoule*, when in fact it is) than in the Verb-Switch condition (where they hear that the penguin is not *pirdaling* when indeed it is now spinning rather than cartwheeling)

2.1 | Method

2.1.1 | Participants

Forty-eight French 18-month-olds participated in the study (24 in each experimental group; mean age = 17.9 months, range = 17.5–18.6 months; *SD* =0.25; 18 girls). The number of participants was chosen on the basis of a power analysis conducted on the effect size found in de Carvalho et al., (2019) and He and Lidz (2017), see our preregistration. Participants were all monolingual native French speakers with less than 20% exposure to another language. An additional 26 infants came to the laboratory, but were not included in the final sample for one of the following reasons: because of fussiness not allowing them to finish the experiment (*n* = 8); because they did not meet the habituation criterion within 12 habituation trials (*n* = 5); because of parental interference (*n* = 5); technical problem (*n* = 1); or because they cried during the experiment (*n* = 7).

2.1.2 | Materials

Two novel words in French (*bamoule* and *pirdale*) were used as target words. For each novel word, four kinds of sentences were created, by crossing two factors, affirmative vs. negative, and noun vs. verb. Thus, each target word appeared as a noun and as a verb in affirmative sentences (e.g., as a noun in: "*Oh regarde! C'est une bamoule! Tu la vois la bamoule?*"; as a verb in: "*Oh regarde! Elle bamoule! Tu la vois qui bamoule?*") and each target word also appeared as a noun and as

a verb in negative sentences (e.g., as a noun in: "*Oh regarde! Ce n'est pas une bamoule! Tu vois? Ce n'est pas une bamoule!*"; as a verb in: "*Oh regarde! Elle ne bamoule pas! Tu vois? Elle ne bamoule pas!*"). To create the audio tracks of the videos, a given sound file with each type of sentence was concatenated 12 times with a short interstimulus interval occupied by an audio prompt (e.g., "Oh"; "Wow"; "Hey") to relieve monotony and keep infants listening to the sentences while watching the videos. This resulted in a 50-s-long audio track for each target word in each condition. The assignment of target words to syntactic categories (noun vs. verb) and the associations with the videos were counterbalanced across participants, such that half of the participants had the target word *pirdale* as a noun and *bamoule* as a verb, and half had the reverse. Half had "spinning" as the verb meaning, and half had "cartwheeling" as the verb meaning. All the stimuli were recorded by a female native speaker of French in child-directed register.

2.1.3 | Apparatus and procedure

Infants sat on their parent's lap, facing a 27-inch monitor and a loudspeaker in a sound-attenuated booth. Parents wore headphones and listened to masking music during the experiment. On top of the monitor, a video camera connected with an LCD monitor placed outside the cabin allowed the experimenter to observe the infants' behavior and code their looking behavior online. The presentation of the stimuli and the online coding were controlled by the Habit software, version 1.0 (Cohen et al., 2004). Each trial started with the presentation of an attention-getter (a silent video of a butterfly perched on a leaf) to attract infants' attention. The experimenter pressed a computer key when the toddler looked toward the screen, and released it when the toddler looked away. If the toddler reoriented toward the screen within 2 s, the video continued to play, but the time spent looking away was subtracted from their looking time. Each trial lasted until the child looked away for more than 2 s, or until the maximum length of the trial was reached (i.e., 50 s). The experimenter was blind to the stimuli.

During the habituation phase, infants were presented with the two video stimuli, showing a penguin doing two different actions (spinning and cartwheeling, one in each video). During the presentation of one of the videos (e.g., spinning), they heard affirmative sentences presenting a novel word as a noun, and during the presentation of the other video (e.g., cartwheeling), they heard affirmative sentences presenting the other novel word as a verb. These videos were presented repeatedly one after the other, until the child reached a predefined habituation criterion (i.e., when the average looking time during any block of three consecutive trials dropped to less than 65% of the average looking time for the three-trial block that had the longest total looking time). Habituation lasted at least four trials and no more than twelve trials.

At test, infants were divided into two groups and were presented with a fixed number of two trials, in which negative sentences were presented, and the noun and verb sentences switched (see Figure 1). Participants assigned to the Negative Noun-Switch trials listened to negative sentences featuring the noun they had learned during the habituation phase, while they watched the video previously associated with the verb (e.g., a penguin cartwheeling). Participants assigned to the Negative Verb-Switch trials listened to negative sentences featuring the verb they had learned during habituation, while they watched the video previously associated with the noun (e.g., a penguin spinning).

2.1.4 | Data processing and analysis

The dependent variable was infants' looking time at the video. To test for increased interest, we compared the average looking time of the last two trials of the habituation phase with that of the two test trials, in each experimental condition (Negative Noun-Switch vs. Negative Verb-Switch). If infants understand the meaning of negative sentences, a greater increase in looking time from habituation to test should be observed in the Negative Noun-Switch condition compared to the Negative Verb-Switch condition. To test this, an ANOVA was performed on the mean looking time (transformed in log because the data did not follow a normal distribution), with Participants as the random factor, Condition as a between-participant factor, and Phase (Habituation vs. Test) as a within-participant factor. The expected effect should appear as a significant interaction between Condition and Phase.

2.2 | Results

Figure 2 presents infants' looking times during the last two trials of the habituation phase and during the two trials of the test phase. The ANOVA revealed a significant interaction between Condition and Phase: $F(1, 46) = 4.24$, $p = .04$; $d = 0.615$; this interaction reflects the fact that infants' looking times increased more between habituation and test in the Negative Noun-Switch condition than in the Negative Verb-Switch condition.

Given that both groups were exposed to exactly the same videos and sentences in the habituation phase, the only way to explain the asymmetry observed in the test phase, is that infants were able to learn the meaning of the novel words during habituation (as established in de Carvalho et al., 2019 and He & Lidz, 2017), to correctly interpret the meaning of the negative sentences, and to evaluate their truth value. Since at test, the associations between the actions and the target words were switched, but the penguin was always present in both videos, a negative sentence saying that the penguin was not doing the previously learned action was true in that context (cartwheeling and spinning are indeed different actions), but negative sentences saying that "It is not a bamoule" (in which "*bamoule*" = "penguin"), were false, since a penguin was still present on the screen. Accordingly, infants in the Negative Noun-Switch condition increased their looking time between habituation and test more than infants in the Negative Verb-Switch condition.

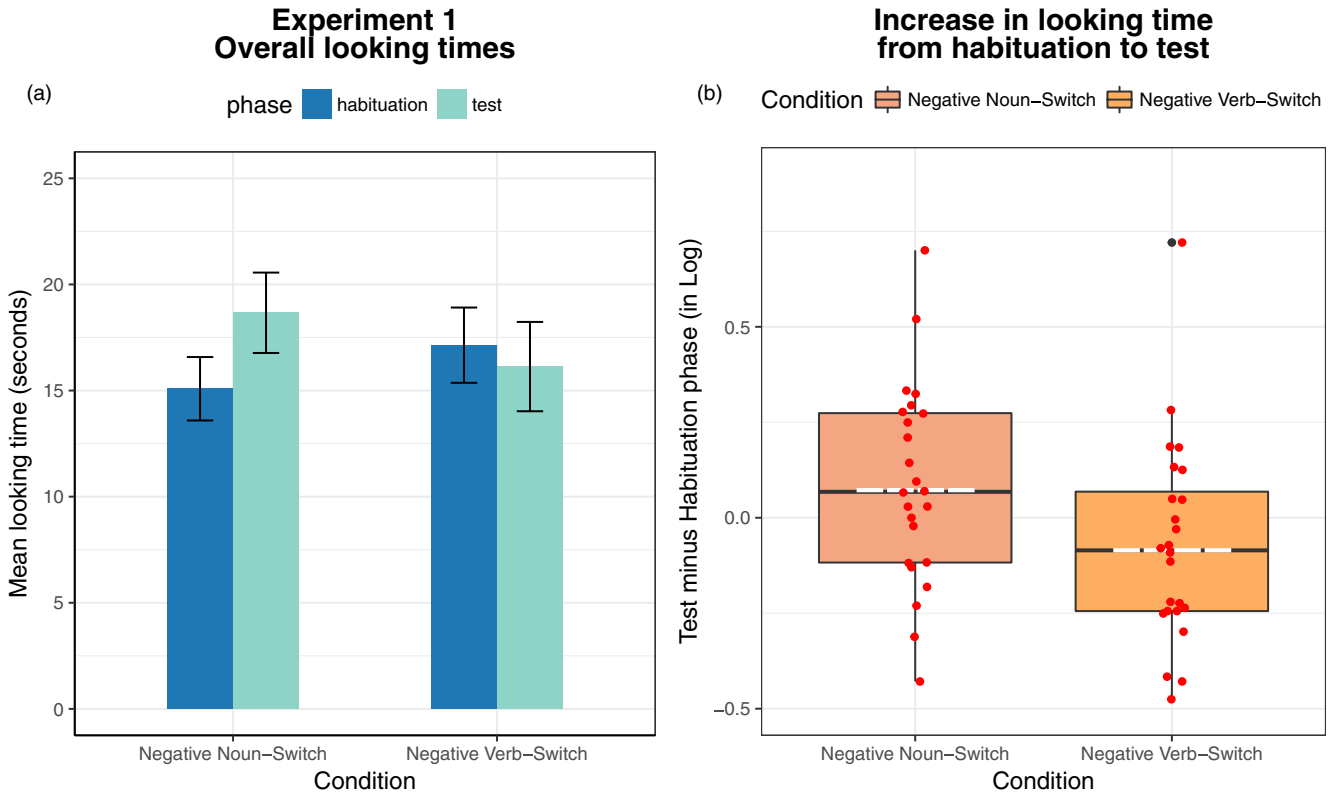

FIGURE 2 On the left side: Mean looking time in seconds toward the videos during the last two trials of the habituation phase (in blue) and during the two trials of the test phase (in green) for children assigned to the Negative Noun-Switch condition (*N* = 24) and to the Negative Verb-Switch condition (*N* = 24). Error bars represent the standard error of the mean. On the right side: Boxplot of the increase in log-transformed mean looking times from habituation to test in each group. Red dots represent the average for each participant in each group. Within each plot, the white dashed lines represent the means of the distributions, and the solid black line in the middle represents the median. The bottom of each box represents the 25th percentile (or first quartile), and the top represents the 75th percentile (or third quartile); the bottom whisker extends to the smallest value (unless it is an outlier), and the top whisker extends to the largest value (unless it is an outlier)

As suggested by two anonymous reviewers, we conducted a direct comparison between the results observed in the current study, which used negative sentences at test, and the previous study of de Carvalho et al., (2019)[2], which used affirmative sentences at test. In that past study, the apparatus and procedure were exactly the same as in the current experiment; the only difference was that the sentences used in the test phase were affirmatives. So in the test phase of de Carvalho et al., (2019, Experiment 1), half of the participants (*n* = 24) was assigned to the Affirmative Noun-Switch trials: they listened to affirmative sentences featuring the noun they had learned during the habituation phase (e.g., "Look! It's a bamoule!"), while they watched the video previously associated with the verb (e.g., a penguin cartwheeling). The other half was assigned to the Affirmative Verb-Switch trials in which they listened to affirmative sentences featuring the verb they had learned during the habituation phase (e.g., "Look! It's pirdaling!") while they watched the video previously associated with the noun (e.g., a penguin spinning). Figure 3 presents infants' looking times during the last two trials of the habituation phase and during the two trials of the test phase in each experiment.

A post hoc joint analysis (ANOVA) of the two experiments (affirmative vs. negative sentences) was conducted on the mean looking time (in log) in the two experiments, with Participants as the random factor, Condition (Noun vs. Verb Switch) and Experiment (Affirmative vs. Negative) as between-participant factors, and Phase (Habituation vs. Test) as a within-participant factor. This analysis revealed a significant triple interaction between Condition, Phase, and Experiment ($F(1, 92) = 9.85$, $p < .003$; $d = 1.015$). This triple interaction reflects the fact that while infants tested with affirmative sentences increased their looking times (between habituation and test) more in the Verb-Switch condition than in the Noun-Switch condition ($F(1, 46) = 5.65$, $p = .022$, $d = 0.665$), infants tested with negative sentences did the reverse and looked longer in the Negative Noun-Switch condition than in the Negative Verb-Switch condition ($F(1, 46) = 4.24$, $p = .04$; $d = 0.615$). These results suggest that whereas in both experiments infants were habituated with the same kind of videos and sentences, the presence of affirmative or negative sentences at test gave rise to very distinct behaviors. Infants tested with affirmative sentences increased their looking times more in the Verb-Switch condition (they heard "It's pirdaling," but the action had changed) than in the Noun-Switch condition (they heard "It's a bamoule" and although the action had changed, there was still a penguin in the screen). In contrast, in the current study, infants tested with negative sentences exhibited the reverse pattern of results: they looked longer in the Negative Noun-Switch condition than in

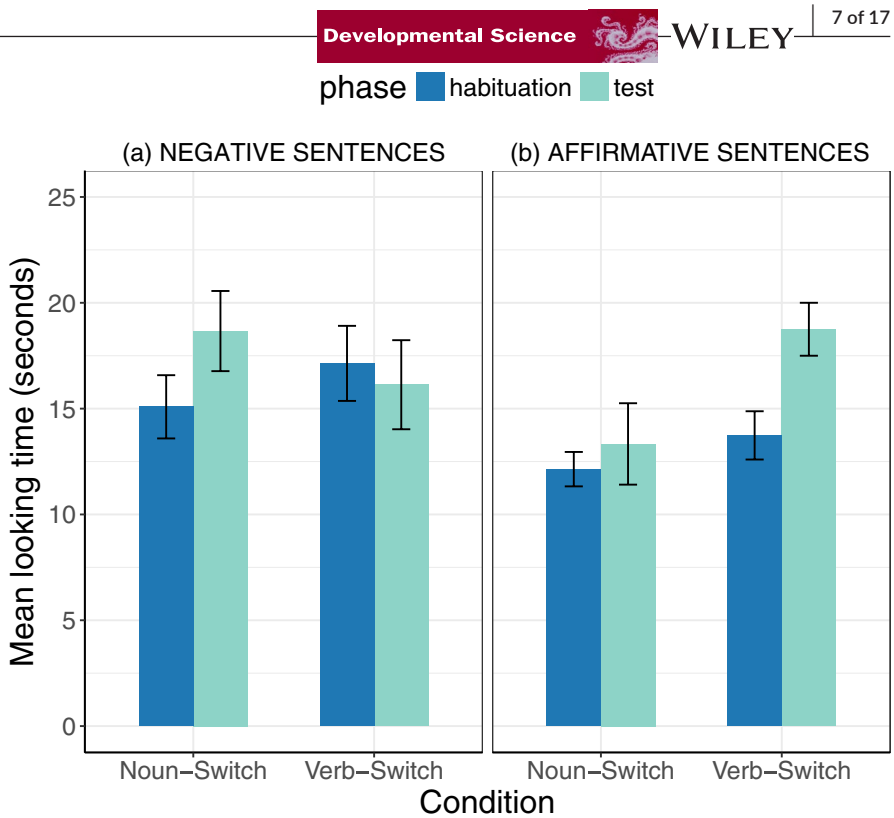

FIGURE 3 Comparison of our current results with negative sentences (a) and the results obtained in de Carvalho et al., (2019—Experiment 1) with affirmative sentences (b). Blue bars represent mean looking time in seconds toward the videos during the last two trials of the habituation phase and green bars represent mean looking time toward the videos during the two trials of the test phase, for children assigned to the Noun-Switch Condition (on the left; *N* = 24 in each experiment) and to the Verb-Switch Condition (on the right; *N* = 24 in each experiment). Error bars represent the standard error of the mean. Note that each trial has a maximal duration of 50 s in the experiment with negative sentences (a) and 37 s in the experiment with affirmative sentences (b)

the Negative Verb-Switch condition, consistent with what was expected if they correctly interpreted negative sentences.

Contrary to previous studies investigating the acquisition of negation with infants younger than 2, here we can clearly conclude that infants did not process negative sentences as if they were affirmatives: the pattern of results we observed is opposite of what was observed with affirmative sentences in de Carvalho et al. (2019).

2.3 | Discussion

These results show for the first time that 18-month-olds are able to understand negative sentences and evaluate whether they are used appropriately, depending on context. After having learnt that *bamoule* means "penguin" and *pirdaling* means "cartwheeling," at test infants looked longer to the videos when listening to negative sentences that were rendered false by their context such as "Look! It is not a *bamoule*!" while watching a penguin cartwheeling. In contrast, they did not increase their looks to the videos at test when listening to a negative sentence that was true in its context such as "*Look! It's not pirdaling!*" while watching a penguin spinning (instead of cartwheeling).

Crucially, this experimental procedure allowed us to observe opposite patterns of behavior for affirmative and negative sentences, showing that 18-month-olds process negative sentences correctly, when they are presented in a supportive context and in a situation that does not require infants to make a choice between two possible interpretations at the same time as they are processing the negative sentences. Our study thus suggests that previous failures in the literature might not be due to infants' inability to process negative sentences *per se*, but rather to some difficulties with the experimental tasks.

The question we now raise is whether children can put to use their understanding of negative sentences to constrain their interpretation of novel word meanings. Note that although Experiment 1 shows that 18-month-olds can understand negative sentences, this experiment alone does not allow us to conclude anything about the role of negative sentences in the acquisition of word meanings. In Experiment 1, participants learned the meaning of "*bamoule*" or "*pirdale*" through their initial exposure to the affirmative sentences (during the habituation phase). At test, negative sentences, containing the words recently learned, simply tested whether infants could detect whether they were used correctly or not, given the context. It is therefore unclear what young children can really learn from a statement like "*It's not a bamoule*." The evidence presented in Experiment 1 suggests that infants understand negative sentences and thus might be able to interpret a sentence such as "It is not a bamoule" to constrain their interpretation of novel word meanings. However, another experiment is required to investigate whether before 27 months, infants can exploit the context of negative sentences, as accurately as they do for affirmative sentences, to constrain their interpretation of word meanings. In other words, if children are exposed to sentences like "It's not a bamoule" while looking at an object for which they don't have a name yet, do they make any inference about what a bamoule might or might not be? This question was investigated in Experiment 2.

3 | EXPERIMENT 2

This experiment directly tested whether toddlers can use their understanding of negative sentences to constrain their interpretation of novel word meanings. Since Experiment 1 shows that

18-month-olds understand negative sentences and since past studies show that before age 2, infants exploit the syntactic/semantic context of sentences to make inferences about novel word meanings (e.g., Bernal et al., 2007; de Carvalho et al., 2019; He & Lidz, 2017; Waxman et al., 2009), we hypothesize that 2-year-olds might be able to integrate the syntactic context of sentences together with the meaning of a negative element in that sentence, to constrain their interpretation of novel word meanings.

In a preferential looking paradigm (Figure 4), French 24-month-olds were first exposed to a teaching phase in which they saw two videos showing a woman talking about a new cartoon character (*a bamoule*). In the first video (common to all participants), the woman "accidentally" sat in front of the television so that participants could not see the cartoon while listening to the sentences: "*Look! It's a bamoule!*" (Figure 4-a). For the second video, participants were assigned to either the affirmative or the negative condition and were able to see what was on the television (e.g., a blue monster, Figure 4-b). In the presence of this cartoon character, participants in the affirmative condition listened to sentences like "*Look! It's a bamoule!*" and in the negative condition, to sentences like "*Look! It's not a bamoule!*"[3]. After the teaching phase, all participants did the same test (Figure 4-c-d) in which they were asked to find the *bamoule* while viewing two images: the familiar cartoon character seen during the second video of the teaching phase (e.g., the blue monster) versus a novel character never seen before (e.g., a red monster). At test, participants assigned to the affirmative condition should look more to the familiar cartoon character than participants assigned to the negative condition.

4 | METHOD

4.1 | Participants

Forty-eight French 24-month-olds participated (mean age = 23.8 months, range = 23.1–24.4 months; *SD* = 0.31; 24 girls). The number of children tested was chosen based on two power

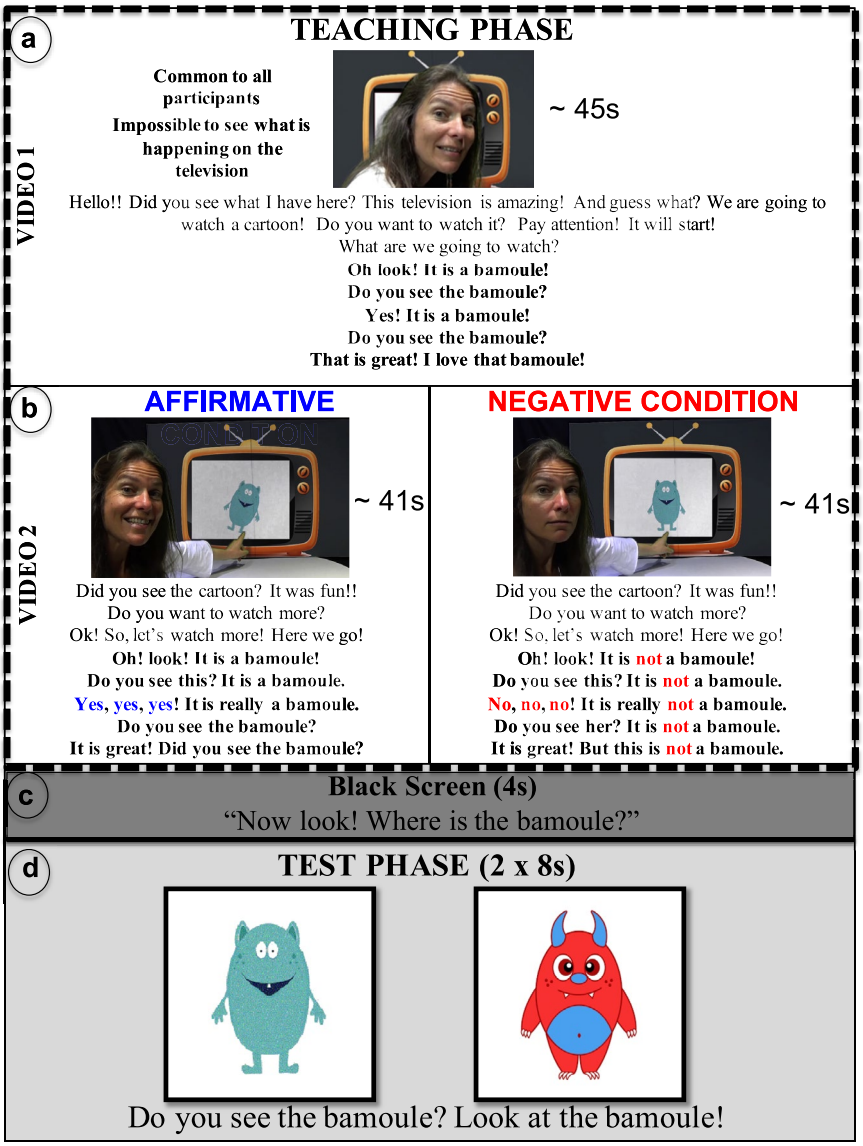

FIGURE 4 (a–d) Experimental design—All participants watched the same Video 1 (a). Then depending on their condition, they watched either the video with affirmative sentences or the video with negative sentences (b). Finally, they all went through the same test phase in which they were asked to find the "bamoule" while they saw the two monsters on the screen and listened to sentences like "*Tu vois la bamoule? Regarde la bamoule!*"—"Do you see the *bamoule*? Look at the *bamoule*!" (c, d). The entire experiment was conducted in French but for lack of space in the figure, we only provide the English translation of each sentence. The presentation of each monster during the teaching phase (i.e., which monster is designated as the bamoule, the red or the blue one) was counterbalanced within conditions such that for half of the participants in each condition the familiar character was the blue monster and for the other half the familiar character was the red monster

analyses conducted on the results of previous studies using a similar experimental design (dialogue phase plus test phase): Arunachalam et al., (2013) and Yuan et al., (2012), see preregistration. Participants were all monolingual with less than 20% exposure to another language. Participants were randomly assigned to one of the two experimental conditions (Affirmative or Negative). The final sample contained 25 participants in the Negative condition and 23 in the Affirmative. An additional thirteen toddlers were not included in the final analysis due to fussiness during the experiment (n = 5), or because they had more than 25% of missing eye-tracking data in the time-window of analysis (first 4 s of the first test trial, n = 8). In addition, 16 adults (8 per condition), participated in the same test to provide us with a baseline.

4.2 | Apparatus

Same as in Experiment 1, except that participants' eye movements were recorded by an eye-tracker Eyelink 1000 (SR Research Ltd.) placed below the screen, and operating in remote mode with a time-sample collected every 2 ms.

4.3 | Material and procedure

The stimuli were two pairs of images illustrating familiar animals for the practice trials, and a pair of images illustrating novel cartoon characters for the test trials. For the teaching phase, three short videos (of about 45 s each) were created: one introductory video (common to all participants), plus one teaching video for each experimental condition (Affirmative vs. Negative).

For practice trials, we chose four animals that children of that age are likely to know: *chat* versus *oiseau*; *chien* versus *canard* (cat vs. bird; dog vs. duck). These pictures were yoked in pairs in each practice trial (e.g., the cat always appeared with the bird and the dog always appeared with the duck). For the novel cartoon characters, we chose two monsters (see Figure 4-d): a red monster (with two horns, big eyes, two sharp teeth and claws on his hands and feet) and a blue monster (with two ears, small eyes, a single and small tooth, and fingers on his hands and feet).

For teaching videos, the introductory video showed a woman talking about a new character that appeared on a television (e.g., a bamoule). The woman started by telling participants that she was going to turn on the television and that they were going to watch a cartoon together. She stands up, turns on the television, but when she sits down again, she "accidentally" sits in front of the television so that the child cannot see the cartoon on the television. The woman pretended she was not aware of this situation, and thus kept talking and uttering several sentences using the novel word "bamoule" such as "Oh look! It is a *bamoule*! Do you see the *bamoule*? I love that *bamoule*!", as if she was introducing what a bamoule was (see Figure 4-a). This introductory video contained five sentences using the novel word in an affirmative noun context. However, participants were unable to learn what the *bamoule* was because they could not see the cartoon on the television.

In the second video, the woman started by saying: "Did you see the cartoon? It was fun! Do you want to watch more? Ok! Let's watch more!". She then stood up again and turned on the television. But this time she did not sit in front of the television and the child was able to see a cartoon character on the screen (see Figure 3-b). For the affirmative teaching video, the woman uttered five affirmative sentences using the novel word, such as "*Oh Look! It is a bamoule!*" while the child saw a cartoon character on the screen. The situation was the same for the negative teaching video, however all five critical sentences containing the novel word were negatives (e.g., "*Oh Look! It is not a bamoule*!"; see Supporting Information for the full transcription of the original sentences). In these videos, we used multiple cues[4] believed to be beneficial to support word learning in toddler's and to help them when processing affirmative and negative sentences (see, e.g., Austin et al., 2014; Baldwin, 1991, 1993, 1995; Graf Estes & Hurley, 2013; Ma et al., 2011; Roseberry et al., 2014). All the videos used in the teaching phase are freely available on OSF (see Materials folder/Videos teaching phase).

The procedure was similar to the preferential looking paradigm developed by Yuan & Fisher (2009) in which participants first watch a dialogue/teaching video showing speakers uttering sentences containing a novel word and then, a test phase assesses the interpretation assigned to the novel word.

The experiment began with a practice block to familiarize toddlers with the procedure. Participants saw two trials involving familiar nouns (i.e., a cat vs. a bird in one trial; and a dog vs. a duck in another trial). In each trial, a pair of images was presented side-by-side, for 8 s, along with a sound track encouraging toddlers to look at one of the pictures. The order of presentation and the side of the targets (left or right) was counterbalanced across participants.

As illustrated in Figure 5, each practice trial started with an inspection period during which each image was presented on one side of the TV screen accompanied by an audio prompt (e.g., "Oh Look! Do you see that?" for 3 s each). A fixation target then appeared (for at least 500 ms) and once participants fixated on it, the two images reappeared side-by-side on the screen for 3 s, without any acoustic stimulus. Next, the two images disappeared, and a sentence containing the familiar target word was presented during a 4-s empty-screen interval (e.g., "Now, look! Where is the *dog*?"). Next, the fixation point reappeared, and once participants fixated on it, the two images reappeared on the screen for 8 s, together with the test sentences repeating the target word twice. After 8 s, the end of the trial presented a baby laughing.

After the practice block, participants started the teaching phase in which they saw the set of videos appropriate for their assigned condition. Two video clips (of approximately 45 s each), separated by a 3-s interval were presented in the middle of the screen: the first introductory video and then either the video of the affirmative or the negative condition. The monster designated as the *bamoule* (red or blue) during the teaching phase (Video 2—Figure 4-b) was counterbalanced within conditions: half of the participants in each condition had the blue monster as the familiar character and half had the red monster.

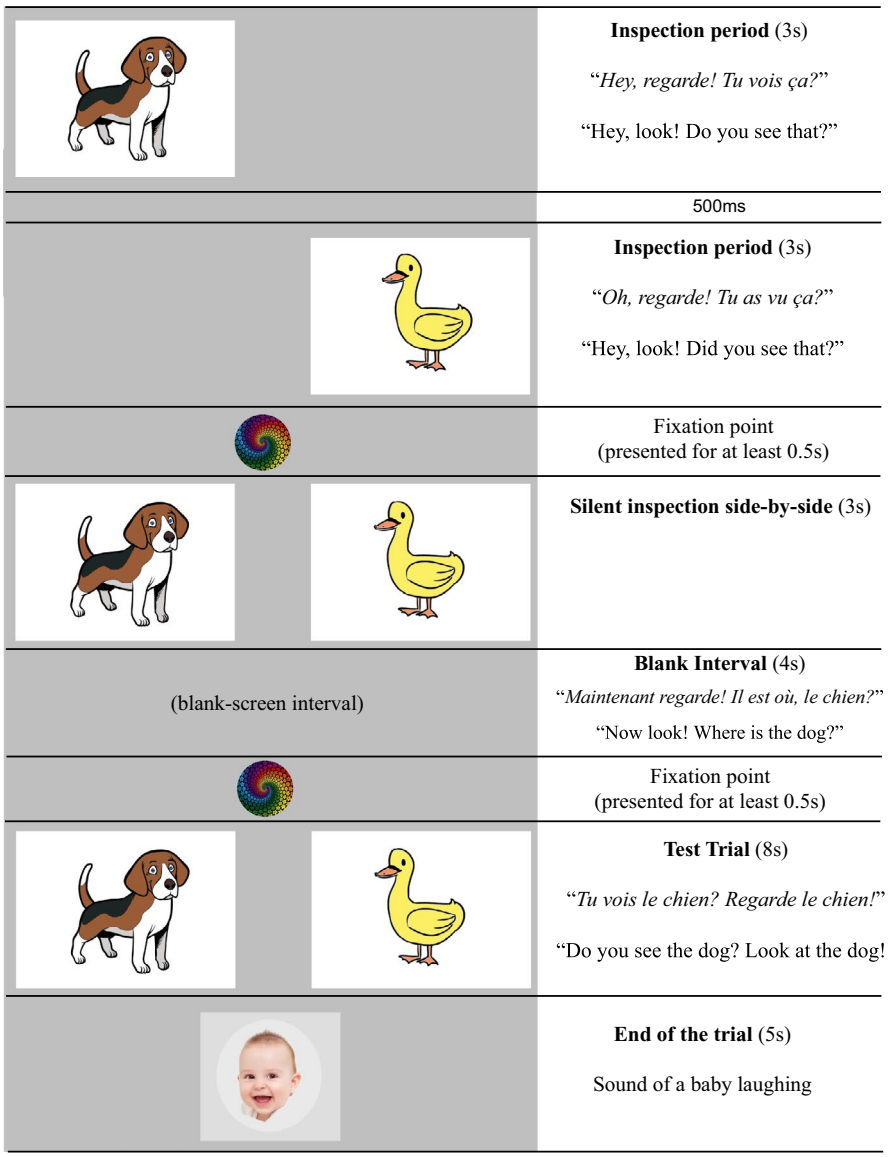

FIGURE 5 Time course of the familiar (practice) trials presentation

Three seconds after the teaching phase, all participants were exposed to the same test (see Figure 6) in which they saw two images side-by-side on the screen (i.e., the familiar character seen during Video 2 vs. a novel character) and they heard sentences asking them to find the *bamoule* (e.g., "Do you see the *bamoule*? Look at the *bamoule*!").

The test was presented in the same way described for the practice trials. However, participants had more time to inspect the pictures (5 s rather than 3 s, because they were illustrating novel animals) and the test trials were repeated twice (to copy the procedure used in previous word-learning studies, e.g., Yuan & Fisher, 2009; Yuan et al., 2012).

4.4 | Data processing and analysis

Before statistical analysis, the data were downsampled by a factor of 10, by averaging the data from 10 adjacent samples (i.e., final sampling rate = 20 ms). During test, all participants listened to the same sound file (asking them to look at the *bamoule*). Our prediction was that the set of sentences heard during the teaching phase (affirmative vs. negative condition) would impact participants' looking preference toward the familiar character at test. Given that looking times toward the familiar versus novel character are complementary (except for looks away which were not significantly different between conditions), the dependent variable analyzed was the proportion of looking times toward the familiar character [looking to the familiar character/(looking to familiar character + novel character)].

To find the time-window(s) with a significant difference between conditions, a cluster-based permutation analysis was conducted (Maris & Oostenveld, 2007). This analysis allows us to test for the effect of Condition on each time point without inflating the rate of Type I error and it proceeds in two steps. First, for each time point, a paired two-tailed *t*-test testing for the effect of Condition (Affirmative vs. Negative) was conducted. All fixation proportions were transformed via the *arcsin* square function to fit better the assumptions of the *t*-test.

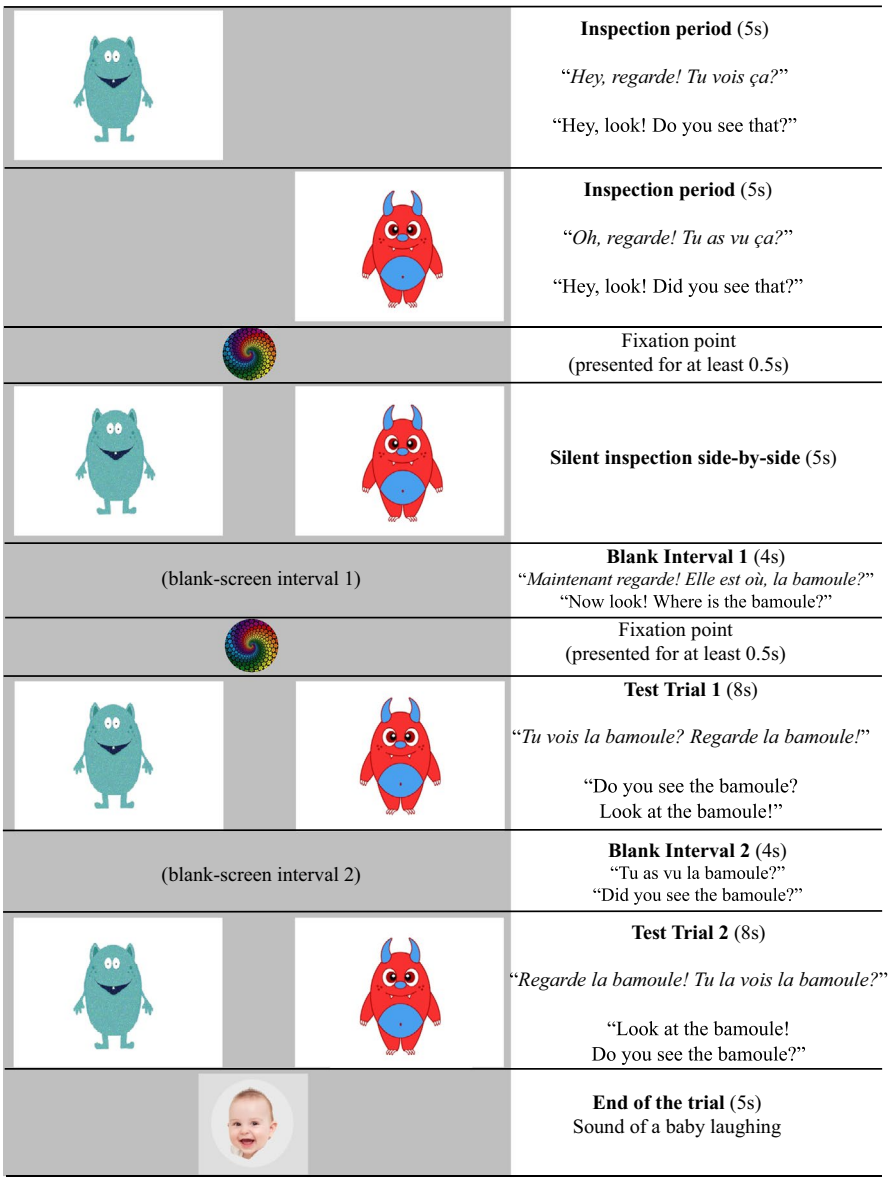

FIGURE 6 Time course of the test trials presentation

The means and variances were computed over subjects between conditions. Adjacent time points with a *t*-value greater than some predefined threshold[5] (here, t = 1.5, as defined in the preregistration), were grouped together into a cluster. Each cluster was assigned a single numerical value measuring its size, defined as the sum of all the *t*-values at each time point within the cluster. Note that a cluster is larger if it contains time-points for which the two conditions are very significantly different, and/or if it spans a longer time-window. Second, to obtain the probability of observing a cluster of that size by chance, 1000 simulations randomly shuffling the conditions (Affirmative and Negative) were conducted. For each simulation, the analysis calculated the size of the biggest cluster identified with the same procedure applied to the real data. A cluster of adjacent time points from the real data shows a significant effect of condition if the sum of the *t*-values in this particular cluster is greater than the highest *t*-value sum from clusters in 95% of the simulations (ensuring a *p*-value of 0.05).

This analysis was conducted on the first 4000 ms of the first test trial[6]. We nevertheless provide the full analysis originally planned and preregistered on OSF (see Supplementary Materials folder on OSF). Additional and exploratory analysis (not preregistered) are also freely available for readers in the Supplementary Materials folder on OSF.

4.5 | Results

Figure 7 shows the proportion of looks toward the familiar character, for participants assigned to the Affirmative condition (blue curve) and participants assigned to the Negative condition (red curve), time-locked to the beginning of the test trial (vertical black line), for 24-month-olds (7-a, on the top) and adults (7-b, on the bottom).

For both age groups, the nonparametric cluster-based permutation test found a significant time-window where the proportion of looks toward the familiar character was significantly different in the Affirmative condition compared to the Negative condition. For 24-month-olds (Figure 7-a), this time-window coincides with the

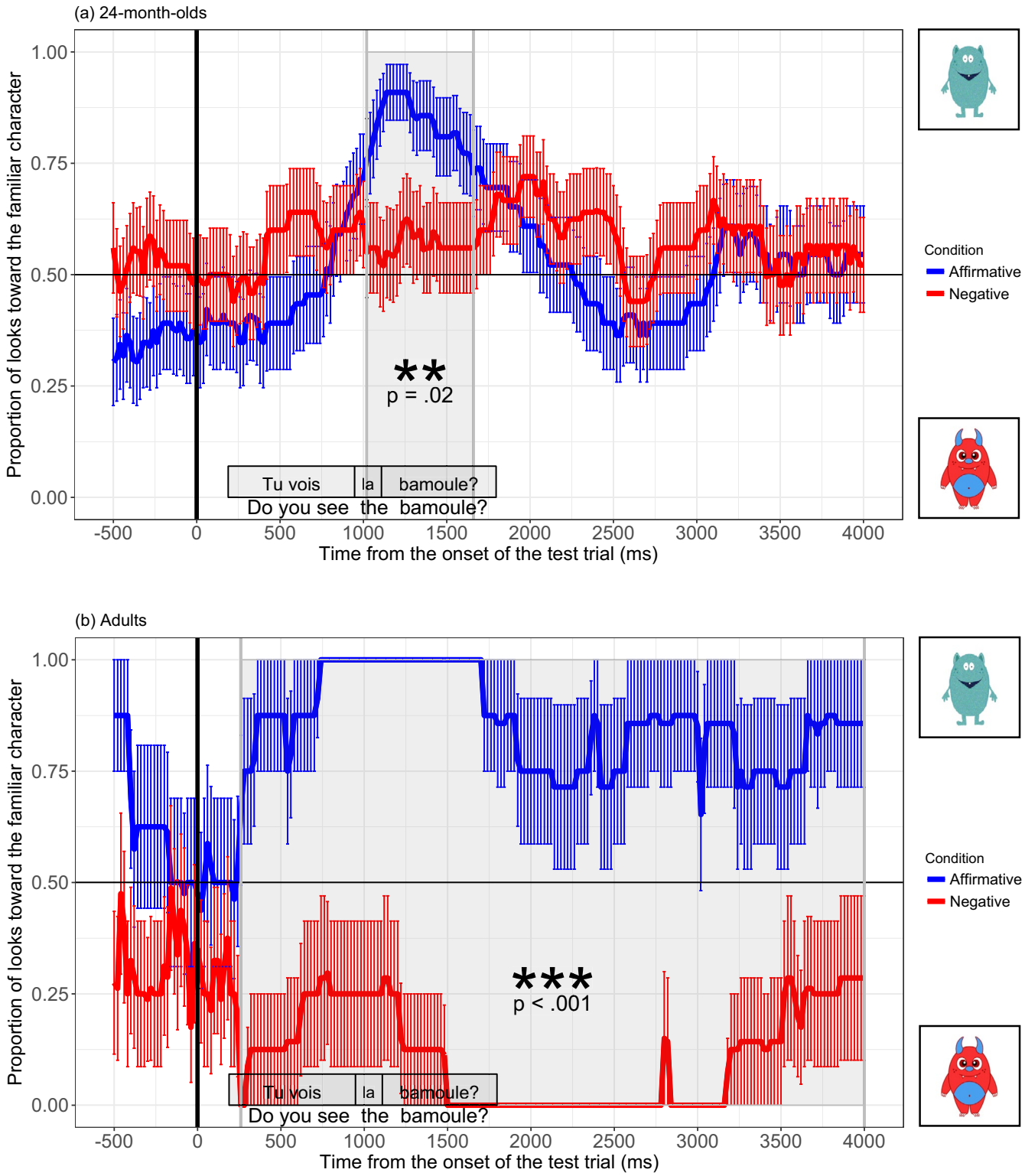

FIGURE 7 Proportion of looks toward the familiar character, time-locked to the onset of the test trial (vertical black line) for (a) 24-month-olds and (b) adults, in the Affirmative condition (blue curve) and in the Negative condition (red curve). Error bars represent the standard error of the mean at each time point. A nonparametric cluster-based permutation test (Maris & Oostenveld, 2007) revealed significant differences between the Affirmative and Negative conditions starting slightly after the onset of the test trial (gray time-window) for both groups: 24-month-olds (from 1020 to 1660 ms,'**'p = .02); and adults (from 260 ms until 4000 ms, '***'p < .001)

onset of the target word "*bamoule*" during the test sentence "Do you see the *bamoule*?" (from 1020 ms after the beginning of the trial until 1660 ms; '**'p = 0.02). For adults, (Figure 7-b), the significant time-window started right after the beginning of the test trial (from

260 ms until 4000 ms, '***'$p < .001$). Adults' anticipatory looks toward the right image from the beginning of the trial suggest that they anticipate their answers right after they heard the sentence during the blank screen interval.

This significant difference between conditions suggests that participants' interpretation of the novel word "*bamoule*" during the test was affected by the condition in which they heard sentences during the teaching phase. Both 24-month-olds and adults looked more to the familiar character in the affirmative condition than in the negative condition. However, while adults in the negative condition (red curve in Figure 7-b) showed a preference for the novel character, toddlers in the negative condition did not show any preference for the novel character[7].

4.6 | Discussion

The results obtained here with 24-month-olds are consistent with the findings of Experiment 1, showing, once again, that infants do not process negative sentences as affirmatives. However, the current experiment provides additional and more direct evidence that toddlers can use their understanding of negative sentences to constrain their interpretation of novel word meanings. Participants who watched a cartoon character on a TV-screen and listened to sentences such as "*It's a bamoule!*" associated the novel word "bamoule" with the cartoon character in front of them. However, participants who watched the same cartoon character and listened to negative sentences such as "*It's not a bamoule!*" did not make the same interpretation and thus did not show any preference for the familiar character during the test, suggesting that negative sentences prevent toddlers to associate the novel word "bamoule" with the cartoon character in front of them.

Because in the negative condition toddlers performed around chance (i.e., no preference for either of the monsters), one might be tempted to conclude that they were confused by the negative sentences and thus, did not learn anything. Although this interpretation would still support our explanation (i.e., they did not learn that the monster in front of them was a *bamoule*), we find it unlikely that toddlers were confused when interpreting negative sentences because 18-month-olds correctly interpreted the same kind of negative sentence, "It is not a *bamoule*," in Experiment 1.

A more reasonable explanation for toddlers' behavior in the negative condition of Experiment 2, is that unlike adults, they had difficulties understanding the pragmatic structure of the experiment, and failed to make an additional inference at test. Adults in the negative condition inferred that the novel cartoon character was the "*bamoule*" because at test, the verbal prompt "Do you see the *bamoule?* Look at the *bamoule!*", implied that there was a *bamoule* on the screen. So, adults used a "mutual exclusivity" strategy, and reasoned that since the familiar character was *not* a *bamoule*, then only the novel character could be "*the bamoule*." One reason why toddlers did not show the same behavior may be because they were unable to make these additional inferences.

There is evidence however that as early as 17 months, infants can use a mutual exclusivity strategy to guess the meaning of novel words (Bion et al., 2013; Byers-Heinlein & Werker, 2009; Golinkoff et al., 1992; Halberda, 2003; Houston-Price et al., 2010; Kalashnikova et al., 2018; Markman & Wachtel, 1988; Markman et al., 2003; Schmale et al., 2012; White & Morgan, 2008): when children are presented with a novel object vs. one or more familiar objects and they hear a novel word (e.g., "Where is the *dofa*?"), they tend to look at the novel object. However, in these studies it is easy for children to map the novel word to the novel object, because they already have a clear label "to eliminate" one of the candidates. The situation is much harder in our task because since the negative sentences simply stated that the familiar character was "not" a bamoule, participants never knew how it was called. So at test, they might have found it hard to choose between two novel referents without having a label for at least one of them.

5 | GENERAL DISCUSSION

The experiments presented here show that from 18 months of age, infants can understand negative sentences and they seem to be able to use this information to constrain their interpretation of word meanings. In Experiment 1, after having learnt that *bamoule* means "*penguin*" from affirmative sentences (e.g., "*Look! It's a bamoule!*"), infants increased their looking times when they later heard negative sentences that were rendered false by the context, such as *Look! It is not a bamoule!*, while watching a penguin cartwheeling. In contrast, they did not change their looking behavior when listening to a negative sentence that was true in its context. In Experiment 2, we found that 24-month-olds not only distinguished between affirmative and negative sentences but they also seemed able to exploit the information conveyed by these sentences to build different hypothesis about the possible meanings of the novel word. Children who witnessed a person label a monster using an affirmative sentence "*It's a bamoule!*" associated the novel word with the monster. However, children who witnessed the person label the monster using a negative sentence "*It's not a bamoule!*" did not make the same association. Together, these studies provide the first evidence for the understanding of negative sentences during the second year of life.

These findings dovetail nicely with what we already know about how children use contrasting semantic information more generally. Several studies suggest that contrasting information (i.e., giving children explicit evidence concerning the limits of the application of novel words) can have facilitative effects in word learning (Au & Markman, 1987; Booth & Waxman, 2003, 2009; Clark, 1988, 1997; Hall & Belanger, 2005; Klibanoff & Waxman, 2000; Namy & Gentner, 2002; Waxman & Markow, 1995). According to these studies, it would be beneficial for a child, who is learning, for example, what "blicket" means, to know what kind of objects can be called "blicket" and what kind of objects cannot be called "blicket" (a situation used in several word learning studies in the literature:

Bernal et al., 2007; Booth & Waxman, 2003, 2009; Gelman et al., 1989; Waxman & Booth, 2001, 2003; Waxman & Klibanoff, 2000; Waxman et al., 2009). Given that negative sentences are one of the linguistic cues available to show children the limits of the application of word meanings, our finding that 18-month-olds can understand negative sentences suggests that they might use this information to support their acquisition of word meanings.

It is worth considering why our studies found infants successfully understanding negation whereas past studies did not, in children younger than 27 months (e.g., Austin et al., 2014; Feiman et al., 2017; Grigoroglou et al., 2019), and sometimes even older (e.g., Kim, 1985; Nordmeyer & Frank, 2014). One possibility would be the differences between the experimental designs used. The other possibility would be a cross-linguistic difference between English and French. The best way to answer this question is to replicate the studies reported here with English-learning infants. If 18- and 24-month-old English-speaking infants succeed in our experiments, as we expect them to, this would suggest that our paradigm was less demanding for young children, for instance, because it did not tax infants' inhibitory skills while they were processing negative sentences. In both Experiments 1 and 2, when participants had to process the negative sentences, they were presented with only a single video, and the sentences were repeated several times, which gave infants ample time to process them correctly. However, if English-speaking infants were to fail in our studies, this will suggest that there are differences between the two languages that make negative sentences easier to learn in French than in English.

It seems unlikely to us that a cross-linguistic difference between English and French children's processing of negative sentences exists, and indeed the information available in the literature leans in this direction. On the one hand, a cross-linguistic study conducted by Choi (1988) investigated both the non-verbal context and the linguistic form of negative utterances in English, French, and Korean-speaking children (aged from 19 to 40 months): the results showed that in all three languages young children possessed the same semantic/pragmatic categories of negation, and their developmental order was similar across the languages. On the other hand, when we looked at when the negative words “no” and “not” in English and their equivalents in French “non” and “pas” enter children's receptive and productive vocabularies in the two languages, based on data from the Macarthur–Bates CDI population norms (Frank et al., 2017; see Supplementary Material folder on OSF), we found that the negative elements used in the current studies, “non” and “pas,” seem to be acquired earlier in French (before 21 months) than “no” and “not” in English (around 28 months). The limitation of these data is that they are based only on parents' intuition of what their children “produce” and “understand,” without taking into account the complexity of the different situations in which negation was used, as the study of Choi (1988) did.

In summary, previous studies about the understanding of negation suggested that before 27 months, infants were unable to interpret negative sentences correctly. This was a serious problem given that a lack of understanding of negative sentences during the second year of life could impact infants' language acquisition. If infants incorrectly interpreted negative sentences as affirmatives, they would face difficulties in learning word meanings. The current study shows that 18- and 24-month-olds do not process negative sentences as affirmatives. Rather, toddlers in this age range successfully integrated syntactic context together with the meaning of negative elements in a sentence to constrain their interpretations of novel word meanings. The ability to understand negative sentences may impact infants' education, since it gives them access to what parents do or “do not” allow them to do. In addition, given that negative sentences can be used to introduce a contrast and give children explicit evidence concerning the space of possible meanings for a word, accurate understanding of such sentences may represent an important tool for infants to constrain their acquisition of word meanings, and to support language acquisition more generally.

ACKNOWLEDGEMENTS

We thank Emmanuel Chemla and Jean-Remy Hochmann for their thoughtful comments on previous versions of this manuscript, Anne-Caroline Fiévet, for her assistance with recruitment of participants, and Elisabeth Lemaitre for her assistance in creating the videos for the teaching phase of Experiment 2.

CONFLICT OF INTEREST

The authors declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

ETHICS APPROVAL STATEMENT

The studies reported in this paper were approved by the local ethics committee (CER Université de Paris).

AUTHORS' CONTRIBUTIONS

Alex de Carvalho and Anne Christophe designed Experiment 1; Alex de Carvalho, Anne Christophe, and John Trueswell designed Experiment 2. Alex de Carvalho, Cécile Crimon, and Axel Barrault performed the research and collected the data. Alex de Carvalho analyzed the data and wrote the manuscript. Anne Christophe and John Trueswell provided critical revisions. All the authors approved the final manuscript for submission.

DATA AVAILABILITY STATEMENT

The studies reported in this paper, including their entire methods, analysis, and criteria for exclusion of participants, were preregistered on the OSF (Open Science Framework) database before running the experiments. The formal preregistrations, the stimuli used, collected data, and data analysis are freely available to readers through the following links: https://osf.io/hgjs6/ (for Experiment 1) and https://osf.io/37uqa/ (for Experiment 2).

ORCID

Alex de Carvalho https://orcid.org/0000-0002-2938-0049

ENDNOTES

[1] Note that this paradigm neatly avoids taxing children's inhibitory/switching abilities, since here the test phase exposes children to one video at a time, without any competition from an alternative interpretation. Moreover, since the test phase is the result of a switch between the audio and the videos presented during the habituation, the context supports the use of negative sentences, to make a contrast between what has been observed before (during habituation) and what infants can currently observe (during test). Presenting negative sentences in supportive contexts is important because previous studies with both adults (Kaup, et al., 2006, 2007; Nordmeyer & Frank, 2015; Tian, et al., 2010) and children (Nordmeyer & Frank, 2014; Reuter et al., 2018) suggest that listeners have difficulties to interpret negation when negative sentences are uttered out of the blue, in pragmatically infelicitous contexts.

[2] The group of participants tested in de Carvalho et al., (2019) with affirmative sentences had similar characteristics than our sample (48 participants, 24 in each group; mean age = 18.1 months, range = 17.7–18.6; *SD* = 0.2; 27 girls). See the method section of de Carvalho et al. (2019) for more details about this study.

[3] As in Experiment 1, this experimental context supports the use of negative sentences: in the first video when the speaker turned the television on, she saw a bamoule on the screen and she was excited about it. In the second video, the situation changed, she was not seeing a bamoule on the screen anymore and that is why she used the negative sentences, to deny the expectation the child may have made that s/he was going to see a bamoule on the screen again.

[4] All sentences were uttered in child-friendly speech; while uttering the sentences, the speaker looked at the camera as if she was directly looking at and talking with the participant as if it were a live and socially contingent interaction; to establish joint attention to the television the speaker tended to look back and forth between the camera and the television as if she and the child were jointly looking at the TV; she also tended to point toward the TV and the objects on the screen while labeling them; and she used some conventional gestures that tend to be associated with affirmative or negative sentences (e.g., head nodding for yes and head shaking for no). In all the videos of the teaching phase, we controlled as much as possible that all the cues that were present in the negative condition video would also be present in the affirmative condition video and vice-versa. For instance, if in the affirmative condition the lady nodded her head "up and down" when saying "yes," in the negative condition she also shook her head "left and right" when saying "no." However, for the negative sentences to be used in a pragmatically felicitous and supportive context, negative and affirmative sentences had to have a slightly different intonation when they were uttered, because it would be very strange to utter a negative sentence with exactly the same "happy" intonation than in an affirmative sentence given that negative sentences in our study were used to express a violation of expectation. Although the lady was always "in a happy mood" in both videos, the intonation of the sentences had to be consistent with the content and context in which the sentences were uttered: in the affirmative condition the lady was "confirming her expectations" when she saw the same object she saw before, while in the negative condition she was a bit "surprised by the violation of her expectation" when she saw that the object on the screen was different from the one she saw before.

[5] Note that the value of the threshold criterion for including a time bin in a cluster ($t > 1.5$ in our study) does not affect the rate of false alarms of the test and is completely independent of the process assessing cluster significance, so it does not affect the likelihood of finding a false positive effect (see e.g., Dautriche et al., 2015).

[6] We had originally planned to conduct this analysis on the entire duration of the test trials (8 seconds), averaged across the two test trials (see our preregistration). However, upon seeing the actual results for the current study we realized that this analysis was inappropriate, because the effect was short-lived: toddlers' orientation toward the target picture was brief (1–2 s) only on the first trial, then they returned to chance looking. The same pattern of results was also observed for familiar trials, for both groups of participants: even though the target word was repeated twice, children did not orient reliably towards the target picture the second time the word was repeated.

[7] Two anonymous reviewers of this paper wondered whether infants could have any default preference for the familiar vs. novel character in each condition that could already be observed before the beginning of the test trials, for instance during the silent inspection period. However, when we analyzed infants looking behavior during the silent period, we did not observe any significant preference (see Supplementary Materials folder on OSF).

REFERENCES

Arunachalam, S., Escovar, E., Hansen, M. A., & Waxman, S. R. (2013). Out of sight, but not out of mind: 21-month-olds use syntactic information to learn verbs even in the absence of a corresponding event. *Language and Cognitive Processes*, *28*(4), 417–425. https://doi.org/10.1080/01690965.2011.641744

Au, T. K., & Markman, E. M. (1987). Acquiring word meanings via linguistic contrast. *Cognitive Development*, *2*(3), 217–236. https://doi.org/10.1016/S0885-2014(87)90059-1

Austin, K., Theakston, A., Lieven, E., & Tomasello, M. (2014). Young children's understanding of denial. *Developmental Psychology*, *50*(8), 2061–2070. https://doi.org/10.1037/a0037179

Baldwin, D. A. (1991). Infants' contribution to the achievement of joint reference. *Child Development*, *62*(5), 875. https://doi.org/10.2307/1131140

Baldwin, D. A. (1993). Infants' ability to consult the speaker for clues to word reference. *Journal of Child Language*, *20*(2), 395–418. https://doi.org/10.1017/S0305000900008345

Baldwin, D. A. (1995). Understanding the link between joint attention and language. In C. Moore & P. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 131–158). Erlbaum.

Bernal, S., Lidz, J., Millotte, S., & Christophe, A. (2007). Syntax constrains the acquisition of verb meaning. *Language Learning and Development*, *3*(4), 325–341. https://doi.org/10.1080/15475440701542609

Bion, R. A. H., Borovsky, A., & Fernald, A. (2013). Fast mapping, slow learning: Disambiguation of novel word-object mappings in relation to vocabulary learning at 18, 24, and 30 months. *Cognition*, *126*(1), 39–53. https://doi.org/10.1016/j.cognition.2012.08.008

Bloom, L. (1970). Syntactic and semantic development of early sentence negation. In L. Bloom (Ed.), *Language development: Form and function in emerging grammars* (Research M, pp. 170–220). MIT Press.

Booth, A. E., & Waxman, S. R. (2003). Mapping words to the world in infancy: Infants' expectations for count nouns and adjectives. *Journal of Cognition and Development*, *4*(3), 357–381. https://doi.org/10.1207/S15327647JCD0403_06

Booth, A. E., & Waxman, S. R. (2009). A horse of a different color:Specifying with precision infants' mappings of novel nouns and adjectives. *Child Development*, *80*(1), 15–22. https://doi.org/10.1111/j.1467-8624.2008.01242.x

Byers-Heinlein, K., & Werker, J. F. (2009). Monolingual, bilingual, trilingual: Infants' language experience influences the development of a word-learning heuristic. *Developmental Science*, *12*(5), 815–823. https://doi.org/10.1111/j.1467-7687.2009.00902.x

Cameron-Faulkner, T., Lieven, E., & Theakston, A. (2007). What part of no do children not understand? A usage-based account of multiword negation. *Journal of Child Language*, *34*(2), 251–282. https://doi.org/10.1017/S0305000906007884

Cepeda, N. J., & Munakata, Y. (2007). Why do children perseverate when they seem to know better: Graded working memory, or directed inhibition? *Psychonomic Bulletin and Review*, *14*(6), 1058–1065. https://doi.org/10.3758/BF03193091

Choi, S. (1988). The semantic development of negation: A cross-linguistic longitudinal study. *Journal of Child Language*, *15*(3), 517–531. https://doi.org/10.1017/S030500090001254X

Clark, E. V. (1988). On the logic of contrast. *Journal of Child Language*, *15*(02), 317–335. https://doi.org/10.1017/S0305000900012393

Clark, E. V. (1997). Conceptual perspective and lexical choice in acquisition. *Cognition*, *64*(1), 1–37. https://doi.org/10.1016/S0010-0277(97)00010-3

Cohen, L., Atkinson, D., & Chaput, H. (2004). *Habit X: A new program for obtaining and organizing data in infant perception and cognition studies (version 1.0)*. University of Texas.

Dautriche, I., Cristia, A., Brusini, P., Yuan, S., Fisher, C., Christophe, A. (2014). Toddlers Default to Canonical Surface-to-Meaning Mapping When Learning Verbs. *Child Development*, *85*(3), 1168–1180. http://dx.doi.org/10.1111/cdev.12164

Dautriche, I., Swingley, D., & Christophe, A. (2015). Learning novel phonological neighbors: Syntactic category matters. *Cognition*, *143*, 77–86. https://doi.org/10.1016/j.cognition.2015.06.003

de Carvalho, A., He, A. X., Lidz, J., & Christophe, A. (2019). Prosody and function words cue the acquisition of word meanings in 18-month-old infants. *Psychological Science*, *30*(3), 319–332. https://doi.org/10.1177/0956797618814131

de Carvalho, A., Dautriche, I., Fiévet, A-C., Christophe, A. (2021). Toddlers exploit referential and syntactic cues to flexibly adapt their interpretation of novel verb meanings. *Journal of Experimental Child Psychology*, *203*, 105017http://dx.doi.org/10.1016/j.jecp.2020.105017

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Doyle, A. W., Friesen, K., Reimer, S., & Pexman, P. M. (2019). Grasping the alternative: Reaching and eyegaze reveal children's processing of negation. *Frontiers in Psychology*, *10*(MAY). https://doi.org/10.3389/fpsyg.2019.01227

Drozd, K. F. (1995). Child English pre-sentential negation as metalinguistic exclamatory sentence negation. *Journal of Child Language*, *22*(3), 583–610. https://doi.org/10.1017/S030500090000996X

Feiman, R., Mody, S., Sanborn, S., & Carey, S. (2017). What do you mean, no? Toddlers' comprehension of logical "no" and "not". *Language Learning and Development*, *13*(4), 430–450. https://doi.org/10.1080/15475441.2017.1317253

Ferguson, B., Graf, E., & Waxman, S. R. (2014). Infants use known verbs to learn novel nouns: Evidence from 15- and 19-month-olds. *Cognition*, *131*(1), 139–146. https://doi.org/10.1016/j.cognition.2013.12.014

Ferguson, B., Graf, E., & Waxman, S. R. (2018). When veps cry: Two-year-olds efficiently learn novel words from linguistic contexts alone. *Language Learning and Development*, *14*(1), 1–12. https://doi.org/10.1080/15475441.2017.1311260

Fisher, C., Hall, D. G., Rakowitz, S., & Gleitman, L. (1994). When it is better to receive than to give: Syntactic and conceptual constraints on vocabulary growth. *Lingua*, *92*(C), 333–375. https://doi.org/10.1016/0024-3841(94)90346-8

Fisher, C., Jin, K., & Scott, R. M. (2020). The developmental origins of syntactic bootstrapping. *Topics in Cognitive Science*, *12*(1), 48–77. https://doi.org/10.1111/tops.12447

Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2017). Wordbank: An open repository for developmental vocabulary data. *Journal of Child Language*, *44*(03), 677–694. https://doi.org/10.1017/S0305000916000209

Gelman, S. A., Wilcox, S. A., & Clark, E. V. (1989). Conceptual and lexical hierarchies in young children. *Cognitive Development*, *4*(4), 309–326. https://doi.org/10.1016/S0885-2014(89)90022-1

Gleitman, L., Cassidy, K., Nappa, R., Papafragou, A., & Trueswell, J. (2005). Hard words. *Language Learning and Development*, *1*(1), 23–64. https://doi.org/10.1038/scientificamerican0491-138

Golinkoff, R. M., Hirsh-Pasek, K., Bailey, L. M., & Wenger, N. R. (1992). Young children and adults use lexical principles to learn new nouns. *Developmental Psychology*, *28*(1), 99–108. https://doi.org/10.1037/0012-1649.28.1.99

Graf Estes, K., & Hurley, K. (2013). Infant-directed prosody helps infants map sounds to meanings. *Infancy*, *18*(5), 797–824. https://doi.org/10.1111/infa.12006

Grigoroglou, M., Chan, S., & Ganea, P. A. (2019). Toddlers' understanding and use of verbal negation in inferential reasoning search tasks. *Journal of Experimental Child Psychology*, *183*, 222–241. https://doi.org/10.1016/j.jecp.2019.02.004

Guidetti, M. (2005). Yes or no? How young French children combine gestures and speech to agree and refuse. *Journal of Child Language*, *32*, 911–924. https://doi.org/10.1017/S0305000905007038

Halberda, J. (2003). The development of a word-learning strategy. *Cognition*, *87*(1), B23–B34. https://doi.org/10.1016/S0010-0277(02)00186-5

Hall, D. G., & Belanger, J. (2005). Young children's use of range-of-reference information in word learning. *Developmental Science*, *8*(1), 8–15. https://doi.org/10.1111/j.1467-7687.2005.00388.x

He, A. X., & Lidz, J. (2017). Verb learning in 14- and 18-month-old English-learning infants. *Language Learning and Development*, *13*(3), 335–356. https://doi.org/10.1080/15475441.2017.1285238

Houston-Price, C., Caloghiris, Z., & Raviglione, E. (2010). Language experience shapes the development of the mutual exclusivity bias. *Infancy*, *15*(2), 125–150. https://doi.org/10.1111/j.1532-7078.2009.00009.x

Hummer, P., Wimmer, H., & Antes, G. (1993). On the origins of denial negation. *Journal of Child Language*, *20*(3), 607–618. https://doi.org/10.1017/S0305000900008503

Jasbi, M., McDermott-Hinman, A., Davidson, K., & Carey, S. (2020). Parents' and children's production of English negation. *Paper presented at the 45th Boston University Conference on Language Development, Boston, MA*.

Jin, K., & Fisher, C. (2014). In W. Orman & M. J. Valleau (Eds.), Early evidence for syntactic bootstrapping: 15-month-olds use sentence structure in verb learning. *Proceedings of the 38h Annual Boston University Conference on Language Development*. Cascadilla Press. Retrieved from http://www.bu.edu/bucld/supplementvol38/

Kalashnikova, M., Escudero, P., & Kidd, E. (2018). The development of fast-mapping and novel word retention strategies in monolingual and bilingual infants. *Developmental Science*, *21*(6), e12674. https://doi.org/10.1111/desc.12674

Kaup, B., Lüdtke, J., Zwaan, R. A. (2006). Processing negated sentences with contradictory predicates: Is a door that is not open mentally closed?. *Journal of Pragmatics*, *38*(7), 1033–1050. http://dx.doi.org/10.1016/j.pragma.2005.09.012

Kaup, B., Yaxley, R. H., Madden, C. J., Zwaan, R. A., Lüdtke, J. (2007). Experiential simulations of negated text information. *Quarterly Journal of Experimental Psychology*, *60*(7), 976–990. http://dx.doi.org/10.1080/17470210600823512

Kim, K. (1985). Development of the concept of truth-functional negation. *Developmental Psychology*, *21*(3), 462–472. https://doi.org/10.1037/0012-1649.21.3.462

Klibanoff, R. S., & Waxman, S. R. (2000). Basic level object categories support the acquisition of novel adjectives: Evidence from preschool-aged children. *Child Development*, *71*(3), 649–659. https://doi.org/10.1111/1467-8624.00173

Landau, B., & Gleitman, L. (1985). *Language and experience: Evidence from the blind child*. Cambridge, MA: Harvard University Press.

Ma, W., Golinkoff, R. M., Houston, D. M., & Hirsh-Pasek, K. (2011). Word learning in infant-and adult-directed speech. *Language Learning*

and Development, *7*(3), 185–201. https://doi.org/10.1080/15475441.2011.579839

Maris, E., & Oostenveld, R. (2007). Nonparametric statistical testing of EEG- and MEG-data. *Journal of Neuroscience Methods*, *164*(1), 177–190. https://doi.org/10.1016/j.jneumeth.2007.03.024

Markman, E. M., & Wachtel, G. F. (1988). Children's use of mutual exclusivity to constrain the meanings of words. *Cognitive Psychology*, *20*(2), 121–157. https://doi.org/10.1016/0010-0285(88)90017-5

Markman, E. M., Wasow, J. L., & Hansen, M. B. (2003). Use of the mutual exclusivity assumption by young word learners. *Cognitive Psychology*, *47*(3), 241–275. https://doi.org/10.1016/S0010-0285(03)00034-3

McNeill, D., & McNeill, N. B. (1967). A question in semantic development: What does a child mean when he says "no"?. In E. Zale (Ed.). *Studies in language and language behavior, progress report IV* (pp. 464–473). Center for Research on Language and Language Behavior, University of Michigan.

Messenger, K., Yuan, S., & Fisher, C. (2015). Learning verb syntax via listening: New evidence from 22-month-olds. *Language Learning and Development*, *11*(4), 356–368. https://doi.org/10.1080/15475441.2014.978331

Naigles, L. (1990). Children use syntax to learn verb meanings. *Journal of Child Language*, *17*(2), 357–374. https://doi.org/10.1017/S0305000900013817

Namy, L. L., & Gentner, D. (2002). Making a silk purse out of two sow's ears: Young children's use of comparison in category learning. *Journal of Experimental Psychology: General*, *131*(1), 5–15. https://doi.org/10.1037//0096-3445.131.1.5

Nordmeyer, A. E., & Frank, M. C. (2014). The role of context in young children's comprehension of negation. *Journal of Memory and Language*, *77*(C), 25–39. https://doi.org/10.1016/j.jml.2014.08.002

Oshima-Takane, Y., Ariyama, J., Kobayashi, T., Katerelos, M., & Poulin-Dubois, D. (2011). Early verb learning in 20-month-old Japanese-speaking children. *Journal of Child Language*, *38*(03), 455–484. https://doi.org/10.1017/S0305000910000127

Pea, R. D. (1980). The development of negation in early child language. In D. R. Oslon (Ed.), *The social foundations of language and thought* (pp. 156–186). W W Norton & Company.

Pozzan, L., Feiman, R., Snedeker, J., Guasti, M. T., Dorn, K., Weinert, S., de Carvalho, A., & Trueswell, J. C. (2019). Not getting ahead of ourselves: A cross-linguistic investigation of children's understanding of negation. In *Paper presented at the 44th Boston University Conference on Language Development (BUCLD). November, 9.*.Boston, MA.

Reuter, T., Feiman, R., & Snedeker, J. (2018). Getting to no: Pragmatic and semantic factors in two- and three-year-olds' understanding of negation. *Child Development*, *89*(4), e364–e381. https://doi.org/10.1111/cdev.12858

Roseberry, S., Hirsh-Pasek, K., & Golinkoff, R. M. (2014). Skype me! Socially contingent interactions help toddlers learn language. *Child Development*, *85*(3), 956–970. https://doi.org/10.1111/cdev.12166

Schmale, R., Cristia, A., & Seidl, A. (2012). Toddlers recognize words in an unfamiliar accent after brief exposure. *Developmental Science*, *15*(6), 732–738. https://doi.org/10.1111/j.1467-7687.2012.01175.x

Suzuki, T., Kobayashi, T. (2017). Syntactic Cues for Inferences about Causality in Language Acquisition: Evidence from an Argument-Drop Language. *Language Learning and Development*, *13*(1), 24–37. http://dx.doi.org/10.1080/15475441.2016.1193019

Syrett, K., LaTourrette, A., Ferguson, B., & Waxman, S. R. (2019). Crying helps, but being sad doesn't: Infants constrain nominal reference online using known verbs, but not known adjectives. *Cognition*, *193*(July), 104033. https://doi.org/10.1016/j.cognition.2019.104033

Tam, C. W. Y., & Stokes, S. F. (2001). Form and function of negation in early developmental Cantonese. *Journal of Child Language*, *28*(2), 373–391. https://doi.org/10.1017/S0305000901004688

Tian, Y., Breheny, R., Ferguson, H. J. (2010). Why We Simulate Negated Information: A Dynamic Pragmatic Account. *Quarterly Journal of Experimental Psychology*, *63*(12), 2305–2312. http://dx.doi.org/10.1080/17470218.2010.525712

Vaidyanathan, R. (1991). Development of forms and functions of negation in the early stages of language acquisition: A study in Tamil. *Journal of Child Language*, *18*(1), 51–66. https://doi.org/10.1017/S0305000900013295

Waxman, S. R. (1999). Specifying the scope of 13-month-olds' expectations for novel words. *Cognition*, *70*(3), B35–B50. https://doi.org/10.1016/S0010-0277(99)00017-7

Waxman, S. R., & Booth, A. E. (2001). Seeing pink elephants: Fourteen-month-olds' interpretations of novel nouns and adjectives. *Cognitive Psychology*, *43*(3), 217–242. https://doi.org/10.1006/cogp.2001.0764

Waxman, S., & Booth, A. (2003). The origins and evolution of links between word learning and conceptual organization: New evidence from 11-month-olds. *Developmental Science*, *6*(2), 128–135. https://doi.org/10.1111/1467-7687.00262

Waxman, S. R., & Klibanoff, R. S. (2000). The role of comparison in the extension of novel adjectives. *Developmental Psychology*, *36*(5), 571–581. https://doi.org/10.1037/0012-1649.36.5.571

Waxman, S. R., Lidz, J. L., Braun, I. E., & Lavin, T. (2009). Twenty four-month-old infants' interpretations of novel verbs and nouns in dynamic scenes. *Cognitive Psychology*, *59*(1), 67–95. https://doi.org/10.1016/j.cogpsych.2009.02.001

Waxman, S., & Markow, D. B. (1995). Words as invitations to form categories: Evidence from 12- to 13-month-old infants. *Cognitive Psychology*, *29*(3), 257–302. https://doi.org/10.1006/cogp.1995.1016

Werker, J. F., Cohen, L. B., Lloyd, V. L., Casasola, M., & Stager, C. L. (1998). Acquisition of word–object associations by 14-month-old infants. *Developmental Psychology*, *34*(6), 1289–1309. https://doi.org/10.1037/0012-1649.34.6.1289

White, K. S., & Morgan, J. L. (2008). Sub-segmental detail in early lexical representations. *Journal of Memory and Language*, *59*(1), 114–132. https://doi.org/10.1016/j.jml.2008.03.001

Yuan, S., Fisher, C., & Snedeker, J. (2012). Counting the nouns: Simple structural cues to verb meaning. *Child Development*, *83*(4), 1382–1399. https://doi.org/10.1111/j.1467-8624.2012.01783.x

Yuan S., Fisher C. (2009). "Really? She Blicked the Baby?": Two-year-olds learn combinatorial facts about verbs by listening. *Psychological Science*, *20*(5), 619–626. http://dx.doi.org/10.1111/j.1467-9280.2009.02341.x

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Carvalho A, Crimon C, Barrault A, Trueswell J, Christophe A. "*Look! It is not a bamoule!*": 18- and 24-month-olds can use negative sentences to constrain their interpretation of novel word meanings. *Dev Sci*. 2021;00:e13085. https://doi.org/10.1111/desc.13085