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Toddlers exploit referential and syntactic cues to flexibly adapt their interpretation of novel verb meanings

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ABSTRACT

Because linguistic communication is often noisy and uncertain, adults flexibly rely on different information sources during sentence processing. We tested whether toddlers engage in a similar process and how that process interacts with verb learning. Across two experiments, we presented French 28-month-olds with right-dislocated sentences featuring a novel verb ("He$_i$ is VERBing, the boy$_i$"), where a clear prosodic boundary after the verb indicates that the sentence is intransitive (such that the NP "the boy" is coreferential with the pronoun "he" and the sentence means "The boy is VERBing"). By default, toddlers incorrectly interpreted the sentence based on the number of NPs (assuming, e.g., that someone is VERBing the boy). Yet, when children were provided with additional information about the syntactic contexts (Experiment 1, N = 81) or the referential/semantic content (Experiment 2, N = 72) of the novel verb, they successfully used the prosodic information as a cue to reach the correct syntactic structure of the sentence and infer the probable meaning of the novel verb. These results suggest that toddlers can flexibly adjust their interpretations of sentences depending on the reliability of the linguistic cues available. Thus, failure to parse a sentence in

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an adult-like fashion might not necessarily reflect the immaturity of children's parsing system but rather might be indicative of what cues children consider reliable in that context.

Introduction

Children learn the meaning of words in part on the basis of the syntactic structure in which a novel word appears, a process known as *syntactic bootstrapping* (Fisher, 1996; Gillette, Gleitman, Gleitman, & Lederer, 1999; Gleitman, 1990; Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2005; Landau & Gleitman, 1985). Syntactic bootstrapping relies on the idea that the meaning of a word or its semantic structure (in the case of a predicate) determines the syntactic structure licensed by the word (Levin & Hovav, 1995). For instance, verbs describing an agent's action on a patient are typically transitive and license two NPs in the sentence (e.g., "The girl is pushing the boy"), whereas verbs describing a participant acting solo are instantiated in intransitive sentences featuring a single NP (e.g., "The girl is jumping"). Children exploit these syntax–semantics relationships and appropriately assign different interpretations to novel verbs presented in different sentence structures (e.g., Arunachalam & Dennis, 2019; Arunachalam, Syrett, & Chen, 2016; Arunachalam & Waxman, 2010; Dautriche et al., 2014; Fisher, 2002; Fisher, Jin, & Scott, 2020; Messenger, Yuan, & Fisher, 2015; Naigles, 1990; Naigles & Kako, 1993; Scott & Fisher, 2012; Suzuki & Kobayashi, 2017; Yuan & Fisher, 2009; Yuan, Fisher, & Snedeker, 2012). For instance, when presented with a novel verb in a transitive sentence such as "The girl is blicking the boy," children readily interpret "blick" as a causal event where a girl is acting on a boy. However, children do not build the same interpretation when the novel verb appears in an intransitive sentence structure such as "The girl is blicking" (e.g., Fisher, 2002; Yuan & Fisher, 2009; Yuan et al., 2012).

Critically, this suggests that children's interpretation of a novel verb may interact with their developing syntactic parsing abilities, that is, their ability to compute the correct syntactic structure of a sentence. For instance, it has been shown that young children initially treat the number of NPs in the sentence as a cue to its semantic predicate argument structure (Fisher, 2002). Although this parsing strategy is efficient in distinguishing transitive sentence structures from intransitive ones, it can also lead to the assignment of erroneous syntactic structures because not all the sentences containing two NPs are necessarily transitive (e.g., Lidz, Williams, & Perkins, 2017). For instance, 21-month-olds provide the same interpretation to a new verb appearing in the sentence "The boy is gorping the girl" and in the sentence "The boy and the girl are gorping" because in both conditions they interpret "gorping" as referring to a causal action between two participants, with the boy acting on the girl (Gertner & Fisher, 2012; see also Lidz, Gleitman, & Gleitman, 2003). These results show that the deployment of certain parsing strategies can lead children to fail to accurately interpret some syntactic structures, as reflected by their understanding of novel verbs in these structures.

Although these failures uncover which parsing strategy is deployed by children to understand a given sentence structure, they do not necessarily indicate the absence of grammatical knowledge for that structure. This is most obvious in a study by Dautriche et al. (2014), where French 28-month-olds were shown to be selective in their application of parsing strategies when interpreting right-dislocated sentences (e.g., "*Il$_i$ dort, le lapin$_i$*" [It$_i$ is sleeping, the bunny$_i$]). The specific prosody of these sentences (in particular an intonational phrase boundary between "sleeping" and "the bunny") should block the interpretation based on the number of NPs because in this case "the bunny" is coreferring to the pronoun "It."[2] Thus, right-dislocated sentences can contain an intransitive verb between two NPs and describe an action with a single participant. The 28-month-olds correctly

[2] Note that a similar type of prosodic structure can be observed in English when we utter a sentence such as "Let's eat, children!" where hopefully children will not be the patient of the action (to eat) but rather the agent.

interpreted right-dislocated sentences containing familiar verbs, such as "*Il*$_i$ *mange, le lapin*$_i$" (It$_i$ is eating, the rabbit$_i$), as meaning "The rabbit is eating," but they failed to assign the correct parse to right-dislocated sentences containing a novel verb (e.g., "*Il*$_i$ *dase, le garçon*$_i$" [He$_i$ is dasing, the boy$_i$]). Instead, toddlers behaved exactly as if they had heard a transitive sentence (e.g., "*Il*$_i$ *dase le garçon*$_k$" [He$_i$ is dasing the boy$_k$]), and they chose to interpret the novel verb "*daser*" as a causal action between two participants. These results show that despite having the appropriate knowledge to understand right-dislocated sentences, children deploy another parsing strategy in the presence of uncertainty about the meaning of the verb. One possible explanation for this behavior is that although children are able to understand right-dislocated sentences containing familiar verbs, they are unable to deploy this knowledge consistently when the context places high demands on the parsing system such as the presence of a novel verb. In this situation, children relied on simpler heuristics—assigning a transitive interpretation for a novel verb based only on the number of NPs in the sentence (assuming, e.g., that a novel verb appearing in a sentence containing two NPs might certainly refer to an action between two participants).

When several parsing strategies are available and lead to conflicting interpretations of a sentence, how could children decide which interpretation to endorse? This question has been extensively studied with adults, and the existing literature suggests that adults choose the most plausible interpretation of a sentence depending on the context, even when this entails altering the sentence structure (Gibson, Bergen, & Piantadosi, 2013; Jaeger, 2010; Levy, 2008; see also Naigles, Fowler, & Helm, 1992, and Naigles, Gleitman, & Gleitman, 1993). For instance, when adults and children were presented with semantically implausible sentences such as "The mother gave the candle the daughter," they preferred to alter the sentence structure ("The mother gave the candle *to* the daughter") in contexts where they believed that the syntax of the sentences was imperfect (e.g., when the experiment contained many small typographical errors involving function words (Gibson et al., 2013; see also Yurovsky, Case, & Frank, 2017, for a similar experiment with preschoolers). The question that arises is whether toddlers can process language in a similarly flexible way and deploy different parsing strategies depending on how plausible they are made by the context. Such flexibility is a critical component of spoken language comprehension because listeners often face temporary ambiguities in the input and thus need to choose between different interpretations of a word or a sentence as sentences unfold (e.g., Woodard, Pozzan, & Trueswell, 2016). Thus, in everyday life, children need to be flexible in the way they interpret and produce words.

To test whether toddlers can deploy different parsing strategies depending on how plausible they are made by the context, we relied on the work of Dautriche et al. (2014) mentioned above, which showed that French 28-month-olds incorrectly expect novel verbs embedded in right-dislocated sentences, such as "*Il*$_i$ *VERB, le garçon*$_i$" ("He$_i$ is VERBing, the boy$_i$," meaning "The boy is VERBing"), to map to a causal action between two participants (assuming that someone else is VERBing the boy), even though they correctly interpret right-dislocated sentences with familiar verbs (e.g., "It$_i$ eats, the bunny$_i$," meaning "The bunny is eating").[3] In this study, children failed to accurately interpret sentences for which they had appropriate grammatical knowledge.

We hypothesized that children's inability to interpret right-dislocated sentences containing novel words reflects a strategy in the presence of uncertainty. When listening to right-dislocated sentences, there are two parsing strategies available to toddlers leading to two possible interpretations: an intransitive one (integrating prosodic information), which they reach when interpreting familiar verbs, and a transitive one (based on the number of NPs in the sentence), which they reach when interpreting novel verbs. We suspect that toddlers relied on the prosodic information to parse sentences with familiar verbs because they had prior knowledge about the syntactic contexts in which these verbs could appear. Given that many transitive verbs can appear in both transitive and intransitive frames (e.g., "Bob ate an apple"; "Bob ate"), and that such verbs are frequent in child-directed speech (e.g., Scott & Fisher, 2009), it is possible that children knew that a verb such as "eat" could

[3] In addition, it is important to note that several studies showed that from 18 months of age, children can use prosodic information to constrain their syntactic analysis (de Carvalho, Dautriche, & Christophe, 2016; de Carvalho, Dautriche, Lin, & Christophe, 2017; de Carvalho, He, Lidz, & Christophe, 2019; de Carvalho, Lidz, Tieu, Bleam, & Christophe, 2016; Hawthorne & Gerken, 2014; Massicotte-Laforge & Shi, 2015, 2020; Snedeker & Yuan, 2008), supporting the idea that 28-month-olds have no problem in using prosody, in general, to comprehend sentences.

be used both in transitive frames containing two NPs (e.g., "The boy is eating an apple") and in intransitive frames containing only one NP (e.g., "The boy is eating") or even in right-dislocated sentences that they may have already heard in their everyday lives (~5% of sentences are dislocated in parents' speech in French; Dautriche, 2012; De Cat, 2007). In this situation, the information provided by prosodic information (suggesting that the verb was used in an intransitive way) was easy to integrate because that information was compatible with the linguistic expectations that children had about this verb. However, when listening to right-dislocated sentences containing a novel verb, toddlers had no prior information on whether or not this novel verb could be used in an intransitive form because they had only heard that novel verb repeated several times in sentences containing two NPs. In this uncertain situation, toddlers might have preferred to rely on the parsing strategy that most often applies for sentences containing two NPs where the first NP is interpreted as the agent of the action and the second NP is interpreted as the patient of the action, as in transitive sentences (see also Gertner & Fisher, 2012; Huang & Arnold, 2016; Huang, Leech, & Rowe, 2017; Huang, Zheng, Meng, & Snedeker, 2013; Messenger & Fisher, 2018).

In the current study, we asked whether toddlers would be able to flexibly adjust their reliance on phrasal prosody versus the parsing heuristics based on the number of NPs, depending on the additional information that they extract from the input. In Experiment 1, we improved children's access to information about the kinds of syntactic structures that the novel verb could enter. Previous research suggests that children can gain information about the meaning of the verb by observing the *set* of syntactic structures in which it appears (e.g., Landau & Gleitman, 1985; Scott & Fisher, 2012). To isolate the effect of syntax on the interpretation of the verb, toddlers were presented with sentences featuring the novel verb without any referential scene before being asked to find the appropriate referent when a visual scene becomes available (as in previous studies; see, e.g., Yuan & Fisher, 2009). We replicated the experiment of Dautriche et al. (2014) with a critical component: In an additional condition, we added simple intransitive frames containing a novel verb along with right-dislocated sentences containing the same verb. Thus, immediately after having heard a right-dislocated sentence, toddlers heard a simple intransitive sentence in which the novel verb was used (e.g., "*Il*$_i$ *dase, le garçon*$_i$*. Ah bon, Il dase?*" [He$_i$ is dasing, the boy$_i$. Really, he is dasing?]). We hypothesized that simply showing toddlers that the novel verb could also appear in intransitive frames (thereby increasing their expectations that the novel verb is intransitive) would increase their reliance on the prosodic information to parse the right-dislocated sentence (i.e., understanding the novel verb as intransitive).

In Experiment 2, we provided additional referential cues presented simultaneously with the test sentences to improve children's access to the novel verb's semantic structure. Although previous research shows that syntactic structures, in the absence of referential scenes, are sufficient to provide some cues about a novel verb's semantic content (e.g., whether it is transitive or intransitive; Yuan & Fisher, 2009), it may still be easier for children to interpret a novel verb when they have access to both its syntactic and referential contexts (see also Grimshaw, 1994). This time, toddlers heard the novel verb in right-dislocated sentences while viewing two simultaneously presented events: one video showing a person performing a self-generated action (a one-participant action) and another video showing a person acting on another person (a causal action between two participants). We tested whether constraining the number of possible semantic interpretations of the novel verb (showing toddlers only two possible videos to match their interpretation) and presenting a matching intransitive event at the same time that children hear the right-dislocated sentences could give more support for them to select the intransitive interpretation of the verb (based on prosody) instead of the transitive interpretation (based on the number of NPs).

In both experiments, we expected that when children interpret the novel verb as transitive, thereby inferring that the verb's meaning involves two participant roles, they should look more toward the two-participant action video than the one-participant video. In contrast, children who interpret the novel verb as intransitive, thereby inferring that the verb's meaning involves one participant role, would not show a preference for any of the events because the intransitive verb could refer either to the one-participant event or to a subcomponent of the two-participant action (Fernandes, Marcus, Di Nubila, & Vouloumanos, 2006; Fisher, 2002; Yuan & Fisher, 2009). Yet, following previous studies (e.g., Arunachalam & Dennis, 2019; Arunachalam & Waxman, 2010; Dautriche et al., 2014;

Fisher, 2002; Matsuo, Kita, Shinya, Wood, & Naigles, 2012; Messenger et al., 2015; Naigles, 1990; Naigles & Kako, 1993; Suzuki & Kobayashi, 2017; Yuan & Fisher, 2009; Yuan et al., 2012), we predicted that participants in the intransitive condition would behave significantly differently from participants in the transitive condition.

Experiment 1

Experiment 1 tested whether toddlers can adjust their reliance on the prosodic information of right-dislocated sentences containing a novel verb when given access to additional information about the syntactic contexts in which the novel verb could appear, namely that it can also appear in intransitive sentences. Following the preferential looking paradigm used in Yuan and Fisher (2009) and in Dautriche et al. (2014), we presented 28-month-olds with dialogues introducing a novel verb, *daser*, in one of four conditions: transitive + intransitive, right-dislocated + intransitive, right-dislocated-only, or intransitive-only (see Fig. 1). In each dialogue condition, toddlers listened to a total of eight sentences containing a novel verb. In the transitive + intransitive condition, they heard four transitive sentences and four intransitive sentences in alternation. In the right-dislocated + intransitive condition, they heard four right-dislocated sentences and four intransitive sentences in alternation. In the right-dislocated-only condition, they heard eight right-dislocated sentences. In the intransitive-only condition, they heard eight intransitive sentences. Right after exposure to one of these dialogues, toddlers were then asked to look for *daser* while watching two videos displayed side by side: a causal action featuring two participants and a one-participant action.

Given that many transitive verbs can appear in both transitive and intransitive frames, we expected that toddlers exposed to the dialogues in the transitive + intransitive condition would still be able to interpret the novel verb as transitive and refer to a two-participant action at test even though this verb appears in transitive and intransitive structures in alternation (see e.g., Naigles, 1996; Naigles, Bavin, & Smith, 2005; Scott & Fisher, 2009, 2012).

Critically, if toddlers flexibly attend to different parsing strategies depending on the information they have, we predicted that listening to the novel verb in intransitive and right-dislocated sentences in alternation may increase the linguistic expectations that the novel verb is intransitive in the right-dislocated + intransitive condition, thereby making it easier for toddlers to rely on the prosodic information to parse the right-dislocated sentence. Because both syntactic structures, intransitive and right-dislocated, would be parsed as intransitive, toddlers would interpret the verb as intransitive, which would surface as no preference for the two-participant action at test. This absence of preference was predicted from previous studies (e.g., Arunachalam & Dennis, 2019; Arunachalam et al., 2016; Arunachalam & Waxman, 2010; Dautriche et al., 2014; Messenger et al., 2015; Yuan & Fisher, 2009; Yuan et al., 2012); if children believe that *daser* refers to a single-participant action, they could either look at the video where there is only one person doing an action (one-participant event) or focus their attention on a component of the two-participant caused motion event (e.g., focusing their attention on the agent of the two-participant action; see the *structure mapping account* in Fisher, 1996, 2002).

The intransitive-only and right-dislocated-only conditions were used to provide baseline conditions—a baseline of how toddlers behave when the syntactic context of right-dislocated sentences was not enriched with intransitive sentences and how toddlers behave when listening only to simple intransitive sentences. We expected the right-dislocated-only condition to replicate the results observed in Dautriche et al. (2014) and show that toddlers incorrectly process these sentences as transitive and look more toward the two-participant action during the test. As established in many previous studies (e.g., Arunachalam & Dennis, 2019; Arunachalam et al., 2016; Arunachalam & Waxman, 2010; Dautriche et al., 2014; Messenger et al., 2015; Yuan & Fisher, 2009; Yuan et al., 2012), toddlers in the intransitive-only condition should not show any preference for the two-participant action during the test.

To summarize, we expected that at test toddlers in the right-dislocated-only condition would behave as toddlers in the transitive + intransitive condition and associate the novel verb with the two-participant causal action. Crucially, however, if the presence of intransitive sentences in the right-dislocated + intransitive dialogue increases the plausibility of the intransitive parse for

Dialogue phase (4 conditions)

---------- Transitive+Intransitive ----------

A: *Hey! Il va daser le papa!*	Hey! He will dase the dad!
B: *Ah bon, il va daser ?*	Really, he will dase?
A: *Oui, et en plus ils ont dasé les garçons.*	Yeah! And they dased the boys.
B: *C'est vrai, ils ont dasé!*	That's right, they dased!
--	--
A: *Tu sais quoi? Elles ont dasé les filles!*	Guess what? They dased the girls!
B: *Quoi, vraiment elles ont dasé?*	What, really they dased?
A: *Oui! Et elle va daser la maman!*	Yes! And she will dase the mom!
B: *Waouh, elle va daser!*	Waouh, she will dase!

---------- Right-dislocated+Intransitive ----------

A: *Hey! Il va daser , le papa!*	Hey! He$_i$ will dase, the dad$_i$!
B: *Ah bon, il va daser ?*	Really, he will dase?
A: *Oui, et en plus ils ont dasé , les garçons.*	Yeah! And they$_i$ dased, the boys$_i$.
B: *C'est vrai? ils ont dasé!*	That's right, they dased!
--	--
A: *Tu sais quoi? Elles ont dasé , les filles!*	Guess what? They$_i$ dased, the girls$_i$!
B: *Quoi, vraiment elles ont dasé?*	What, really they dased?
A: *Oui! Et elle va daser , la maman!*	Yes! And she$_i$ will dase, the mom$_i$!
B: *Waouh, elle va daser!*	Waouh, she will dase!

---------- Right-dislocated only ----------

A: *Hey! Il va daser , le papa!*	Hey! He$_i$ will dase, the dad$_i$!
B: *Ah bon, il va daser , le papa?*	Really, he$_i$ will dase, the dad$_i$?
A: *Oui, et en plus ils ont dasé , les garçons.*	Yeah! And they$_i$ dased, the boys$_i$.
B: *C'est vrai? ils ont dasé , les garçons!*	That's right, they$_i$ dased, the boys$_i$!
--	--
A: *Tu sais quoi? Elles ont dasé , les filles!*	Guess what? They$_i$ dased, the girls$_i$!
B: *Quoi, vraiment elles ont dasé , les filles?*	What, really they$_i$ dased, the girls$_i$?
A: *Oui! Et elle va daser , la maman!*	Yes! And she$_i$ will dase, the mom$_i$!
B: *Waouh, elle va daser , la maman!*	Waouh, she$_i$ will dase, the mom$_i$!

---------- Intransitive only ----------

A: *Hey! Il va daser !*	Hey! He will dase!
B: *Ah bon, il va daser ?*	Really, he will dase?
A: *Oui, et en plus ils ont dasé.*	Yeah! And they dased.
B: *C'est vrai? ils ont dasé!*	That's right, they dased!
--	--
A: *Tu sais quoi? Elles ont dasé !*	Guess what? They dased!
B: *Quoi, vraiment elles ont dasé ?*	What, really they dased?
A: *Oui! Et elle va daser !*	Yes! And she will dase!
B: *Waouh, elle va daser!*	Waouh, she will dase!

Fig. 1. Sample of dialogues in Experiment 1 for the four conditions: transitive + intransitive, right-dislocated + intransitive, right-dislocated-only, and intransitive-only. The dialogues were split into two 24-s videos containing four sentences each separated by a 3-s black screen. Transitive + intransitive and right-dislocated + intransitive dialogues were composed of exactly the same words and differed only in their prosodic structures, reflecting their different syntactic structures.

right-dislocated sentences, toddlers in this condition should behave like toddlers in the intransitive-only condition and thus should not show any preference for the causal action between two participants. If so, this experiment should show that toddlers can use the information provided by multiple syntactic contexts to flexibly parse sentences, as evidenced by their interpretation of novel verbs in these sentences.

Method

The stimuli, data, and analyses of the experiments reported in this article are freely accessible to readers on the Open Science Framework (OSF) database (https://osf.io/b5yqp/?view_only=7b34cd9ddba94da28adc1f8958c25fab).

Participants

A total of 81 French 28-month-olds participated in this experiment (M_{age} = 28.0 months, *SD* = 0.7, range = 26.9–30.2; 40 girls), with 20 in the right-dislocated-only condition, 22 in the right-dislocated + intransitive condition, 18 in the intransitive-only condition, and 21 in the transitive + intransitive condition. All participants were native French speakers with less than 20% exposure to another language. An additional 36 children participated in the experiment but were not included in the final analysis because of fussiness during the experiment (n = 5), distraction during the dialogue phase (n = 6), side bias (n = 1), unusable test trials with missing eye-tracking data (n = 21), exposure to other languages besides French at home (n = 1), or technical problems (n = 2). Parents signed an informed consent form. This research was approved by the local ethics committee.

Participants were recruited from the greater Paris area through direct contact with parents belonging to our local database (these children can be assumed to come from middle- to high-socioeconomic-status homes).

Apparatus

Toddlers were tested individually in a sound-attenuated double-walled booth. They sat on a parent's lap, facing a 42-inch television positioned 70 cm away from them. Toddlers' eye movements were recorded by an eye-tracker EyeLink 1000 (SR Research Ltd., Ottawa, Ontario, Canada) placed below the screen and operating in a remote mode with a time sample collected every 2 ms. The caregivers wore opaque glasses, and the experimenter stayed outside the testing room during the test.

Materials and procedure

The stimuli used in this experiment were videos of two women conversing (for the dialogue phases) and videos of people performing actions (for the test phase). The videos of actions were accompanied by soundtracks recorded by a female native French speaker (the last author).

The procedure was similar to that of Dautriche et al. (2014) and Yuan and Fisher (2009). The experiment was composed of three blocks: practice, dialogue, and test. The practice block was composed of two practice items involving familiar verbs: one intransitive (either *danser* [to dance] or *marcher* [to walk]) and another transitive (either *pousser* [to push] or *porter* [to carry]). These practice items consisted of two 8-s test trials in which a synchronized pair of videos was presented side by side on the screen along with audio that encouraged toddlers to look at one of the videos. For instance, for the familiar verb "*marcher*" (to walk), participants saw two videos played side by side, a girl walking in one video and a girl dancing in the other video, while children heard the stimulus sentence "*Tu la vois qui marche? Regarde celle qui marche!*" (Do you see her walking? Look at the one who is walking!).

To provide participants with enough time to inspect each of the videos individually, each video was first presented alone for 5 s on the left or right side of the screen and a neutral audio prompt was played at the same time (e.g., "*Hey, regarde là! Tu as vu ça?*" [Hey, look here! Did you see that?]) before the test trials started (see, e.g., Fig. 2). The target items were counterbalanced across participants, such that half of the participants were tested on *danser* (to dance) and the other half on *marcher* (to walk). The order and side of presentation of the videos were also counterbalanced across participants, such that half of the participants had the intransitive trial first (e.g., "*danser*" vs. "*marcher*") and the

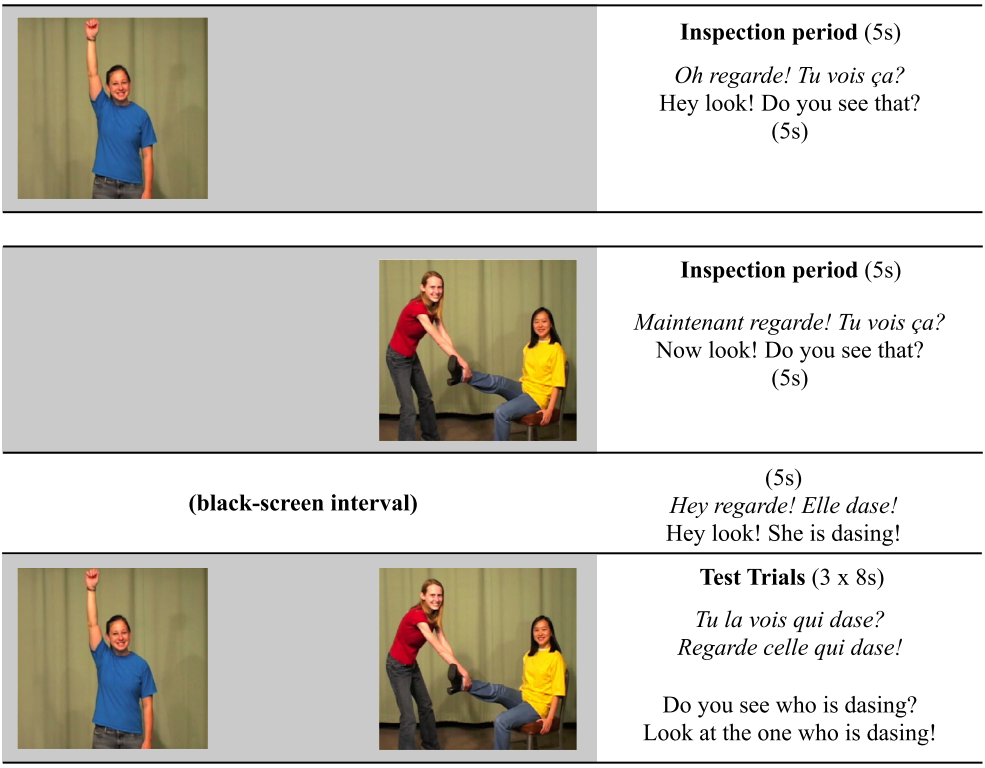

Fig. 2. Time course of the test phase of Experiment 1. After watching the dialogue videos, participants were presented with two novel action videos that were first individually presented on a different side of the screen for 5 s. Then the two videos were presented simultaneously side by side on the screen for 8 s (in each of the three test trials) and participants were asked to look at the one who was "*dasing*."

transitive trial second (e.g., "*pousser*" vs. "*porter*") and the other half had the reverse. Within each trial, half of the participants saw the target video on the left side and the other half saw it on the right side.

The purpose of the practice items was to familiarize participants with the task (i.e., to show them that only one of the two videos matched the soundtracks they heard). After the practice block, participants started the dialogue block in which they saw a dialogue between two women speaking in child-friendly speech where they used the novel verb *daser* in one of four experimental conditions. In this block, two four-sentence dialogue video clips of 24 s separated by a 3-s interval were presented in the middle of the screen. Thus, each participant was exposed to eight sentences: four transitive and four intransitive sentences in alternation for the transitive + intransitive condition; four right-dislocated and four intransitive sentences in alternation for the right-dislocated + intransitive condition; eight right-dislocated sentences in the right-dislocated-only condition; and eight intransitive sentences in the intransitive-only condition (see Fig. 1 for the entire list of sentences in each condition).

Participants started the test block 3 s after the end of the dialogue phase. The test block presented participants with two videos illustrating two novel actions. One video showed an action executed by a single participant (a girl making circles with her right arm), and the other video showed a causative action between two participants (a girl swinging another girl's leg). (The same test videos were used in Yuan and Fisher, 2009, and Dautriche et al., 2014.)

The novel action videos were presented following the same procedure as the practice block: inspection period first and then both videos displayed side by side on the screen for 8 s. The only difference

was that the test trials were repeated three times. During each test trial, participants heard two sentences featuring the novel verb in an intransitive syntactic structure: "*Tu la vois qui dase? Regarde celle qui dase!*" (Do you see who is dasing? Look at the one who is dasing!) (see Fig. 2).

Note that the auditory stimuli in the test trials were identical for all participants.

Acoustic analysis

Given that the transitive and dislocated sentences had exactly the same words but differed only with respect to their prosodic structures (which reflect their different syntactic structures), we assessed the difference between conditions by conducting an acoustic analysis of the stimuli on the segments preceding the critical region (verb) using Praat (Boersma & Weenink, 2020). There was a clear prosodic boundary between the verb and final NP in the dislocated sentences but not in the transitive sentences. The last syllable of the novel verb *daser* (i.e., the syllable *er* just before the prosodic boundary) in the right-dislocated sentences was longer than the same segment in the transitive sentences (M_{trans} = 199 ms vs. M_{disloc} = 621 ms), $t(6) = 5.71$, $p < .01$.

In addition, the pitch drop between the last vowel of the novel verb *daser* and the first vowel of the final NP (e.g., max pitch on the *e* from *daser* minus max pitch on the *ə* from "*le papa*" [the daddy]) was larger in right-dislocated sentences compared with transitive sentences (M_{trans} = − 6.07 Hz vs. M_{disloc} = − 101.15 Hz), $t(3) = 13.17$, $p < .001$. Note that there were no pauses between the verb and the final NP, which ensures that to differentiate the transitive sentences from the right-dislocated ones, toddlers needed to interpret the prosodic structure of the sentences rather than just ignore any lexical material occurring after a pause.

A pilot experiment with naive adults (N = 10) asked participants to listen to each of the sentences used in the dialogues and decide who was performing the action. Participants listened to each of the sentences through headphones. For each trial, they listened to a sentence (e.g., "*Elles$_i$ ont dasé, les filles$_i$*" [They$_i$ dased, the girls$_i$]) and at the same time read a sentence presented in the middle of a computer screen asking them "Who dased?" Below the question, on the right side of the screen they saw a box containing one answer ("*Les filles*" [The girls]) and on the left side they saw a box containing another answer ("*Quelqu'un d'autre*" [Someone else]). Participants then pressed the right or left arrow on the computer keyboard to indicate their answer. The results showed that participants interpreted transitive and right-dislocated sentences correctly more than 94% of the time. That is, they chose the postverbal NP (e.g., "The girls") 94% of the time when listening to right-dislocated sentences, whereas they selected that answer only 6% of the time when listening to transitive sentences.

Criteria for trial and participant exclusion

We removed trials with more than 25% of data missing. Participants were excluded if they did not provide at least one valid trial (out of three trials). This resulted in a total of 227 valid trials (M = 2.8 per participant).

Measurement and statistical analysis

In this experiment, during the test phase all participants listened to the same sound files (asking them to look toward the one who was *dasing*). Our prediction was that the dialogues they heard before the test would affect their looking preference toward the two-participant action at test. Given that the looking times toward the two-participant action and toward the one-participant action are nearly complementary (except for the away looking time, which was not reliably different between conditions), the dependent variable was the proportion of looking times toward the two-participant action, computed for each time bin of 50 ms (obtained by averaging from an initial sampling frequency of 2 ms).

We conducted two analyses. The first analysis looked at the time course of eye movements to the two-participant action. To find whether there was a time window in which children looked toward the two-participant action significantly more in one condition than in another, we conducted six cluster-based permutation analyses on the entire duration of the test trials (from 0 to 8000 ms) to compare the conditions pairwise. Note that the same kind of analysis was used in several other eye-tracking studies with young children in the literature (e.g., Dautriche, Swingley, & Christophe, 2015; de Carvalho, Babineau, Trueswell, Waxman, & Christophe, 2019; de Carvalho, Dautriche, Lin, &

Christophe, 2017; Ferguson, Graf, & Waxman, 2018; Hahn, Snedeker, & Rabagliati, 2015; Von Holzen & Mani, 2012; see Maris & Oostenveld, 2007, for a formal presentation of the analysis itself). The main advantage of the cluster-based permutation analysis is that it allows us to find a time window where we observe a significant effect without needing to select it arbitrarily. This analysis involves two steps: (a) the identification of time windows that have a potential effect and (b) the statistical test itself, which quantifies whether these effects are likely to have been generated by chance. For each time point, a *t* test comparing the proportions of looks toward the two-participant action between two conditions was calculated. Adjacent time points with a *t* value greater than some predefined threshold ($t > 1.5$ on arcsin-transformed data) were grouped together into a cluster. The size of the cluster was defined as the sum of the *t* values of each time point within the cluster. To obtain the probability of observing a cluster of that size by chance, we conducted 1000 simulations where the conditions were randomly shuffled. For each simulation, we computed the size of the biggest cluster identified with the same procedure that was applied to the real data. A cluster of adjacent time points from the real data shows a significant effect if its size is greater than the size of the largest cluster found in 95% of the simulations (ensuring a *p* value of .05).

The second analysis compared proportions of looking time toward the two-participant event across conditions. This is the analysis traditionally used in these verb-learning paradigms, and we provide it here for comparison with previous studies (in French: Dautriche et al., 2014; in English: Yuan & Fisher, 2009). It also allows us to compare all the conditions together in the same statistical model structure (which is not possible within the framework of the first analysis). We modeled the proportion of looking times toward the two-participant event for each trial in a mixed logit model with a fixed predictor condition (four modalities: transitive + intransitive, right-dislocated + intransitive, right-dislocated-only, and intransitive-only) and a random participant effect. The model was specified as Prop_to_2P ~ Condition + (1 | Participant) and was used on data averaged at the trial level on the whole trial duration, such that each participant had one to three data points. Because the dependent variable is a continuous variable in the [0; 1] interval and is a mean of nonindependent samples, we used the *glmmTMB* package in R to model it with a beta distribution.

Hypotheses

We expected toddlers in the right-dislocated-only condition to behave as toddlers in the transitive + intransitive condition and associate the novel verb with the two-participant action. Crucially, however, if the presence of intransitive sentences in the right-dislocated + intransitive dialogue increases the plausibility of the intransitive parse for right-dislocated sentences, toddlers in this condition should behave like toddlers in the intransitive-only condition and thus should not show any preference for the two-participant action.

Results

Time course of eye movements to the two-participant action

Fig. 3A shows the time course of eye movements toward the two-participant action across conditions.

A cluster-based analysis revealed that children in the right-dislocated-only condition looked significantly more at the two-participant action than children in the intransitive condition (from 2600 until 4650 ms, $p < .01$) (see Fig. 3D), which is a replication of Dautriche et al. (2014). Thus, toddlers in the right-dislocated-only condition used the number of NPs in the sentence, rather than the prosodic information, to parse right-dislocated sentences and attribute a causal meaning to a novel verb in those sentences.

Critically, when toddlers heard the novel verb in both right-dislocated and intransitive sentences (the right-dislocated + intransitive condition), they looked less at the two-participant event than toddlers in the right-dislocated-only condition (from 2000 until 3350 ms, $p < .05$) (see Fig. 3C). Thus, toddlers who heard right-dislocated sentences in alternation with intransitive sentences did not interpret the novel verb *daser* as referring to a two-participant action, unlike toddlers who heard the novel verb only in right-dislocated sentences. This suggests that providing more information about the syntactic

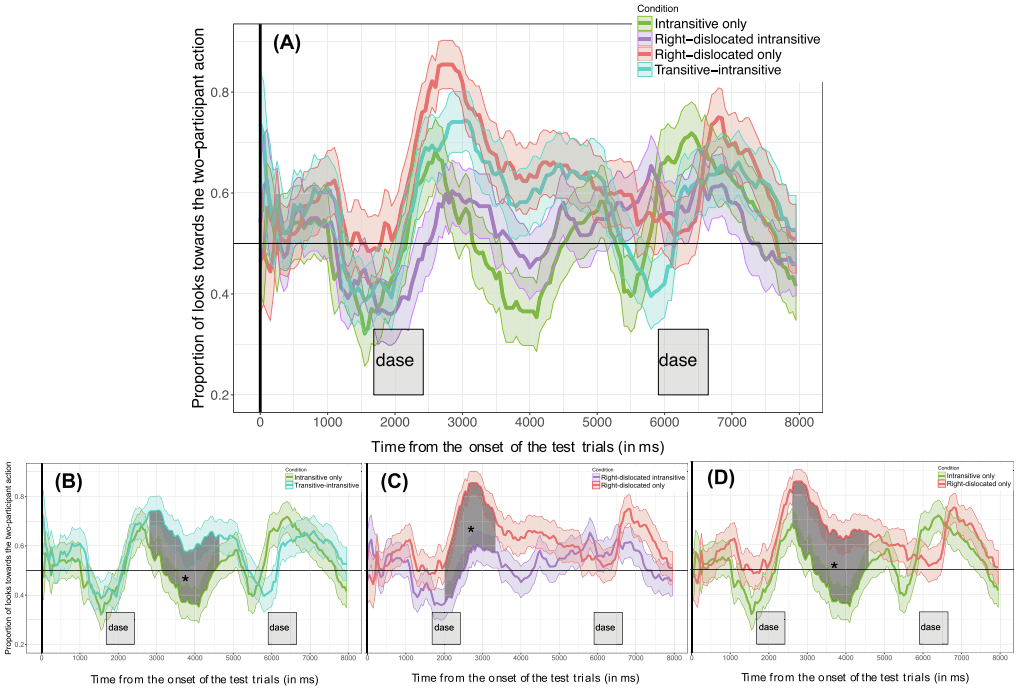

Fig. 3. (A) Proportions of looks toward the two-participant action, time-locked to the onset of the test trials (vertical black line), for toddlers in the intransitive-only condition (green curve), the right-dislocated + intransitive condition (purple curve), the right-dislocated-only condition (red curve), and the transitive + intransitive condition (blue curve). (B–D) Nonparametric cluster-based permutations (Maris & Oostenveld, 2007) performed on the whole duration of the test trials (8 s) revealed significant differences between the transitive + intransitive and the intransitive conditions (B), between the right-dislocated only and right-dislocated + intransitive conditions (C), and between the right-dislocated only and intransitive conditions (D) (all *p*s < .05 in time windows indicated by the black shaded area). No other pairwise comparisons were significant. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

contexts of a novel verb helped children to correctly interpret right-dislocated sentences as intransitives, in accordance with their prosodic structure.

Children in the transitive + intransitive condition also looked more at the two-participant action than children in the intransitive-only condition (from 2800 until 4700 ms, $p < .05$) (see Fig. 3B). This suggests that children in the transitive + intransitive condition interpreted the novel verb in these sentences as transitive. Thus, adding intransitive sentences during the dialogue phase does not invariably bring children to disprefer the two-participant action and behave as if they had heard the novel verb in intransitive sentences only. No other pairwise comparisons between conditions were significant.

As the results from the cluster-based analysis showed, the effect of condition was located a few hundred milliseconds after the first target word onset but was not observed in the remaining second half of the trials. Critically, because most of the previous studies using this paradigm reported only the average looking times over the whole trial duration and not the time course of looks (e.g., Dautriche et al., 2014; Yuan & Fisher, 2009; Yuan et al., 2012), it is unclear whether the effect we should observe in this kind of experimental design is peaked in a specific time window (as is usually the case in word recognition tasks involving nouns; e.g., Bion, Borovsky, & Fernald, 2013; Dautriche et al., 2015; Ferguson, Graf & Waxman, 2014, 2018; Fernald, Zangl, Portillo, & Marchman, 2008; Schmale, Cristia, & Seidl, 2012; Swingley & Aslin, 2000) or is continuous and stable over time. The time windows of effects we found, although relatively small (i.e., with durations from 1.3 to 2.0 s), are consistent with several previous studies using this same experimental design. For instance, in Arunachalam, Escovar, Hansen, and Waxman (2013), effects of verb learning with 21-month-olds were observed from 1.5 to

4.0 s from the onset of the first target verb but not after. In Arunachalam (2013), 27-month-olds were relatively faster in this kind of task, with the effect of condition being observed from 1.0 to 2.5 s after the first onset of the target verb. In both of these studies, the effects lasted for about 1.5 s. Given this literature, and because averaging target looks across the whole trial may mask local responses that do not persist over the whole trial duration, we decided to perform our second analysis on the time window starting at the onset of the target word (1685 ms after the start of the trial) until the halfway point of the trial duration (4000 ms).

Proportions of overall looking times toward the two-participant event across conditions

As represented in Fig. 4, looking times toward the two-participant action in that time window were affected by dialogue conditions, $\chi^2(3) = 12.62$, $p < .01$. Similar to the results of the cluster-based analyses, toddlers in the right-dislocated-only condition looked more toward the two-participant action than toddlers in the intransitive-only condition ($\beta = 0.75$, $z = 2.83$, $p < .01$) and toddlers in the right-dislocated + intransitive condition ($\beta = -0.78$, $z = -3.07$, $p < .01$). Toddlers in the transitive + intransitive condition looked more at the two-participant event than children in the intransitive-only condition ($\beta = 0.52$, $z = 1.96$, $p < .05$).

In addition, toddlers in the transitive + intransitive condition also looked reliably more toward the two-participant action than children in the right-dislocated + intransitive condition ($\beta = 0.52$, $z = 1.96$, $p < .05$). Note that this effect was not present in the cluster-based analysis, suggesting that this effect is weaker than the other reported effects found in both analyses.

No other difference between conditions was significant ($p > .10$).

Discussion

Experiment 1 shows that from 28 months of age, French toddlers processing right-dislocated sentences were able to flexibly adjust their reliance between the prosodic information (leading to an intransitive interpretation) and the number of NPs in the sentence (leading to a transitive interpretation), depending on the different syntactic contexts in which the novel verb appeared.

We replicated previous findings showing that when hearing right-dislocated sentences containing a novel verb (e.g., "He_i is VERBing, the $baby_i$"), toddlers incorrectly associate the novel verb with a causal action between two participants (Dautriche et al., 2014). Thus, in the absence of any additional information about the novel verb, toddlers rely on the number of NPs to parse the sentence, ignoring the prosodic information in reaching their interpretation. However, when children are provided with additional information about the syntactic structures in which the novel verb can enter (intransitive sentences altogether with right-dislocated sentences), they correctly interpret the verb in these structures as intransitive. This suggests that simply listening to a novel verb presented in intransitive and right-dislocated sentences in alternation increased the linguistic expectation that the novel verb is intransitive, thereby making it easier for toddlers to rely on the prosodic information to parse right-dislocated sentences.

Could it be that intransitive sentences simply primed children to look less at the two-participant event in the right-dislocated + intransitive condition? If participants are primed by intransitive sentences to look less at the two-participant action, we would expect that children exposed to a novel verb in both transitive and intransitive sentences would also be primed. Yet, we found that these children associated the verb with a causal action between two participants, much like children exposed to solely transitive sentences or right-dislocated sentences (Dautriche et al., 2014; Yuan & Fisher, 2009). Although this does not completely exclude the possibility of a priming effect from the intransitive sentences, because children could still be less likely to look at the two-participant action than if they were exposed to only transitive sentences, we believe that this is unlikely for two reasons. First, there is no difference in looking behavior between children in the transitive + intransitive condition and children in the right-dislocated-only condition, who in a previous study displayed the same behavior as children exposed to transitive sentences only (Dautriche et al., 2014). Second, if we look at the average proportion of looks toward the two-participant action over the total trial duration (the single measure reported in previous studies), there is no difference between the transitive + intransitive condition

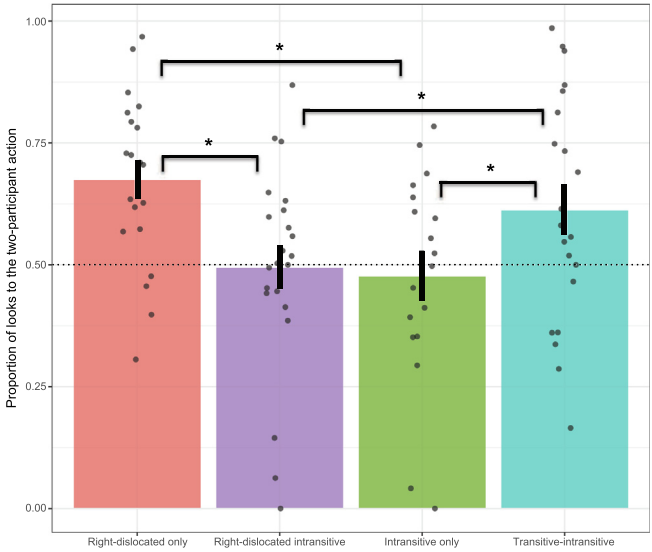

Fig. 4. Proportions of looks toward the two-participant action averaged on the time window starting at the onset of the target word (1685 ms after the start of the trial) until half of the trial duration (4000 ms) for participants in the right-dislocated-only condition (red; left column), the right-dislocated + intransitive condition (purple; second column from left), the intransitive-only condition (green; third column from left), and the transitive + intransitive condition (blue; right column). Error bars represent the standard error of the mean. Dots represent individual data points. Asterisks indicate significant differences between conditions.

(M = 0.56, SE = 0.03) and the transitive condition of Dautriche et al. (2014) (M = 0.54, SE = 0.05). This suggests to us that the presence of intransitive sentences is unlikely to have a priming effect that could explain the difference we see between the right-dislocated-only condition and the right-dislocated + intransitive condition.

Previous studies showed that toddlers construct different interpretations for novel verbs presented in transitive sentences versus intransitive sentences and that child-directed speech contains a lot of transitive verbs that can appear in both transitive and intransitive structures (e.g., Scott & Fisher, 2009). In the current experiment, we extended these findings by showing that toddlers can still learn the meaning of a novel verb even when it appears in alternation between two different types of syntactic structures (see also Naigles, 1996, and Naigles et al., 2005, for a similar pattern of results in a different experimental design). In other words, 28-month-olds were more likely to associate a novel verb with a two-participant action even when the verb was presented in both transitive and intransitive sentences.

These findings dovetail nicely with the findings of Arunachalam et al. (2013), demonstrating that toddlers can exploit additional linguistic cues to avoid a parsing bias. For instance, whereas 21-month-olds mistakenly interpret sentences such as “The boy and the girl are gorping” as referring to a causative action between two participants, Arunachalam and colleagues (2013) demonstrated that toddlers do not construct this wrong inference if, just after this sentence, they hear another intransitive frame with a pronoun in the place of the conjoined subject (e.g., “The boy and the girl are gorping. Really? They are going to gorp?”). Note, however, that in the transitive condition this study presented children with only transitive frames (e.g., “The boy gorped the girl. Really? The boy gorped the girl?”). This suggests that pronominalization was the cue that might have helped toddlers to process “The boy and the girl” as a single NP subject in the intransitive condition. In our experiment, however, both the transitive + intransitive and right-dislocated + intransitive conditions contained the same intransitive syntactic frames, and all sentences were composed of exactly the same words. Thus, toddlers’ success in our task cannot be simply explained by the presence of disambiguating syntactic information but rather can be explained by the rational integration that toddlers were able to do when

processing transitive + intransitive sentences in one condition versus right-dislocated + intransitive sentences in the other condition. Transitive + intransitive sentences gave rise to a final transitive interpretation for the novel verb, whereas right-dislocated + intransitive sentences gave rise to a final intransitive interpretation.

Taken together, our results show that toddlers are able to flexibly rely on different parsing strategies depending on the knowledge they have accumulated about the novel verb's syntactic realization. Relying on the fact that toddlers incorrectly associate novel verbs presented in right-dislocated sentences with a two-participant action, the current experiment shows that when the syntactic context is enriched with simple intransitive sentences, toddlers reach the correct interpretation of the verb. Thus, an interesting follow-up question is whether other sources of information could also help children to recover from a parsing heuristic based on the number of NPs in the sentence.

In real life, it is reasonable to assume that young children may sometimes have the opportunity to observe the extralinguistic contexts coincident with the verb's use and thus could also use this kind of information to constrain their interpretation of novel verb meanings (e.g., Gentner, 1982; Gentner & Boroditsky, 2001; Gillette et al., 1999; Gleitman, 1990; Gleitman et al., 2005; Gleitman & Trueswell, 2020; Naigles et al., 1993). Thus, observing possible referential scenes together with a novel verb may also influence toddlers' reliance on different linguistic cues and may help toddlers to avoid certain parsing biases because these observations would constrain the range of possible interpretations for the verb. In the current case, children may depart more easily from a (wrong) transitive interpretation of right-dislocated sentences if they could observe an event that is compatible with an intransitive interpretation while processing right-dislocated sentences.

To test this hypothesis, we conducted a second experiment asking whether introducing toddlers to fewer candidate interpretations for the novel verb would affect their parsing strategy.

Experiment 2

In Experiment 2, we gave children the opportunity to observe two possible referential scenes while listening to right-dislocated sentences featuring novel verbs. We tested whether the prosodic information in right-dislocated sentences (suggesting that the novel verb is intransitive) would be easier to integrate given that this information would be compatible with the possible semantic representation observed in one of the scenes (e.g., an action being performed by a single participant). In other words, we wanted to test the hypothesis that presenting toddlers with a matching intransitive event (a single-participant event) while processing right-dislocated sentences would help them to avoid the parsing biases attested in previous studies with right-dislocated sentences and therefore increase their reliance on the prosodic information to interpret the novel verbs. Note that simultaneously presenting two videos at the same time as participants are processing the sentences should make the task easier for children because they only need to choose the event matching the sentence they hear rather than build a semantic representation of the verb based on the sole linguistic input they hear (as was the case during the dialogue phase in Experiment 1).

When presented with a video of one person doing an action alone versus the video of two persons involved in a causal action, toddlers simultaneously listening to transitive sentences containing a novel verb (e.g., "He is gorping him") should look more toward the causal action than toddlers listening to intransitive sentences (e.g., "He is gorping") (see Yuan et al., 2012). In the current experiment, we aimed to evaluate the role that the presence of these videos side by side would play in the interpretation of right-dislocated sentences containing a novel verb. As we mentioned before, we believe that toddlers listening to right-dislocated sentences have two parsing strategies available: one based on the number of NPs (which leads to a transitive interpretation of the novel verb) and another based on the prosodic information (which leads to an intransitive interpretation of the verb). Here, we investigated whether introducing toddlers to fewer candidate interpretations for the novel verb (i.e., a choice between two videos) and presenting a suitable referent event for an intransitive interpretation at the same time that children hear the right-dislocated sentences could give more support for them to select the intransitive interpretation of the verb (based on prosody) instead of the transitive interpretation (based on the number of NPs). In other words, in Experiment 2 the presence of the videos during

sentence processing should help toddlers in the same way that adding the intransitive sentences helped in Experiment 1; we give them a little bit more information about the possible contexts in which the novel verb can fit, and we let them decide which strategy is more appropriate to build their interpretations.

Toddlers listened to right-dislocated sentences such as "*Il*$_i$ *fome, le garçon*$_i$" ("He$_i$ is foming, the boy$_i$," meaning "The boy is foming"), or transitive sentences such as "*Il*$_i$ *fome le garçon*$_k$" ("He$_i$ is foming the boy$_k$," meaning "Someone else is foming the boy"), while watching two videos side by side on a television screen: one video showing a person performing a self-generated action (one-participant action) and another video showing a person acting on another (a causative action between two participants).

If constraining the possible realizations of the novel verb (thereby introducing the possibility that the verb refers to a single-participant event) provides cues to the verb's semantic content and help children to depart more easily from a (wrong) transitive interpretation of right-dislocated sentences, children in the right-dislocated condition should look less toward the two-participant action than children in the transitive condition. In addition, we tested a third group of toddlers on intransitive sentences such as "*Il dase*" (He is dasing) to provide us with a baseline of how children behave in this experiment when they hear simple intransitive syntactic frames. Following previous studies using a similar paradigm, we expected that children in the transitive condition would look reliably longer toward the two-participant action than children in the intransitive condition (e.g., Yuan & Fisher, 2009; Yuan et al., 2012).

Method

Participants

A total of seventy-two 28-month-olds (M_{age} = 27.7 months, *SD* = 0.5, range = 26.7–29.0; 36 girls) participated in this experiment. All were monolingual native French speakers with less than 20% of exposure to another language. Of these participating toddlers, 24 were randomly assigned to each of the three experimental conditions: transitive, right-dislocated, or intransitive. An additional 12 toddlers completed the experiment but were not included in the final sample because of fussiness during the experiment resulting in more than 50% of trials with missing eye-tracking data (n = 9), crying during the experiment (n = 2), or technical problems (n = 1). Parents signed an informed consent form. This research was approved by the local ethics committee.

Participants were recruited from the greater Paris area through direct contact with parents belonging to our local database (these children can be assumed to come from middle- to high-socioeconomic-status homes).

Apparatus

The apparatus was similar to that of Experiment 1 except that the experiment took place in a different sound-attenuated booth (IAC - Industrial Acoustics Company Ltd., Hampshire, Winchester, USA) and used a 27-inch television screen to present the stimuli.

Materials

Materials consisted of four pairs of videos showing actors performing simple novel actions. In each pair of videos, one video presented an actor performing a self-generated action (one-participant action) and another video presented an actor acting on another person (a causative action between two participants). Each pair of videos was used to illustrate the possible interpretations of each of the four novel verbs used in the experiment: *fomer, daser, raner,* and *nuver* (see Fig. 5 for action descriptions).

In addition, one pair of videos illustrating familiar actions was recorded. One video presented a familiar intransitive action ("*marcher*" [to walk]) and showed a boy walking, and the other video presented a familiar causative action ("*porter*" [to carry]) and showed a boy carrying another boy. For familiar and novel verb actions, all actors on the screen had the same gender so that toddlers could not use the gender of the pronouns to determine which action was talked about. Each actor appeared in only one video.

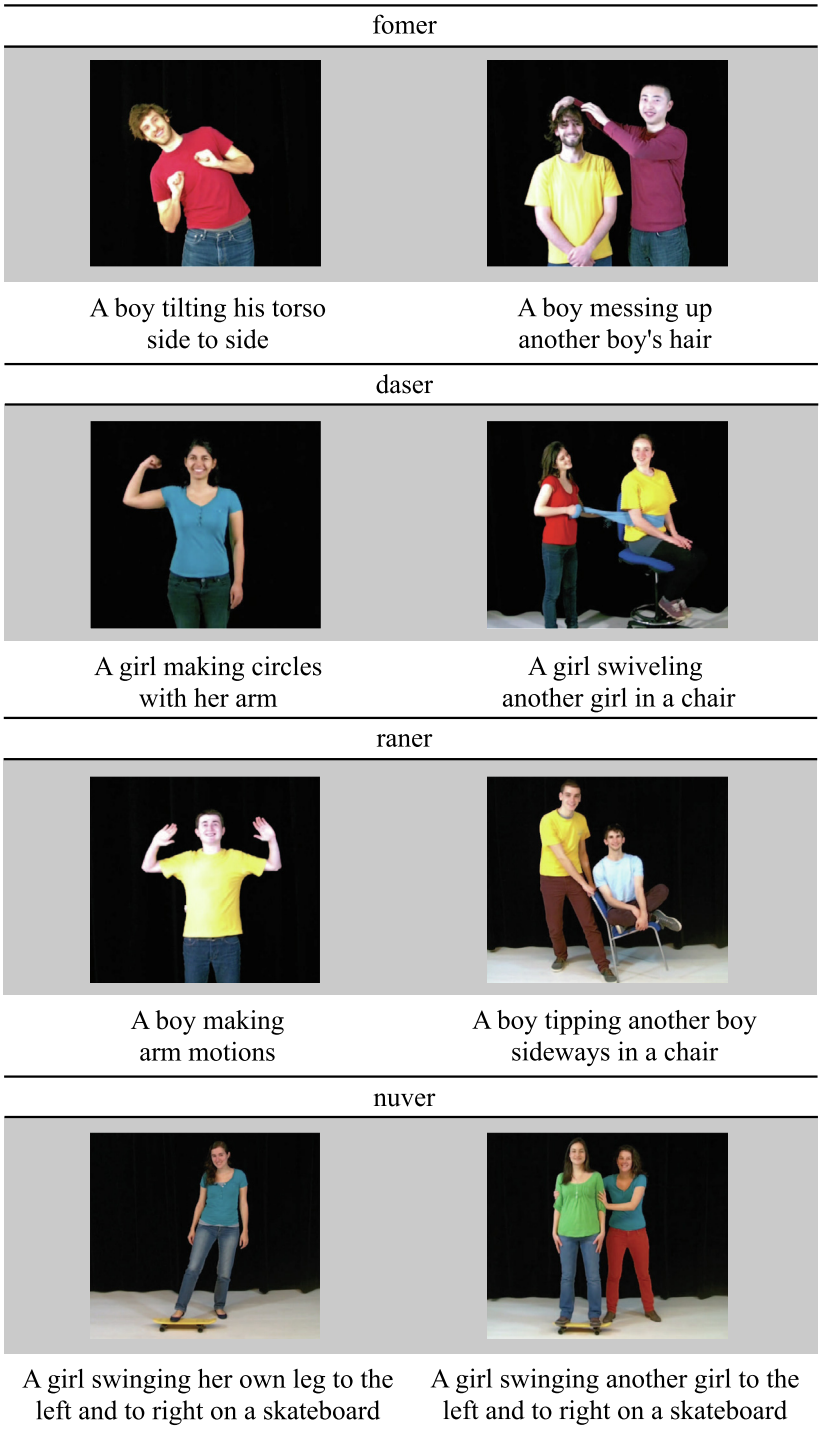

Fig. 5. Novel verbs and actions used in Experiment 2.

All videos were accompanied by soundtracks recorded by a female native French speaker (the last author), who uttered all sentences in child-friendly speech. These soundtracks presented the novel verbs in each of the three experimental conditions (transitive, right-dislocated, or intransitive). The soundtracks for the transitive condition presented the target verb in transitive structures such as "*Tu vois ça? Il$_i$ fome le garçon$_k$. Regarde! Il$_i$ fome le garçon$_k$*" (Do you see that? He$_i$ is foming the boy$_k$. Look! He$_i$ is foming the boy$_k$.). In the right-dislocated condition, the target verb was presented in right-dislocated structures such as "*Tu vois ça? Il$_i$ fome, le garçon$_i$. Regarde! Il$_i$ fome, le garçon$_i$*" (Do you see that? He$_i$ is foming, the boy$_i$. Look! He$_i$ is foming, the boy$_i$.). In the intransitive condition, the novel verb was presented in intransitive structures such as *Tu vois ça? Il fome. Regarde! Il fome*" (Do you see that? He is foming. Look! He is foming.). Note that on each soundtrack for every trial, the target verb was repeated twice.

Acoustic analyses using Praat (Boersma & Weenink, 2020) revealed that, as in Experiment 1, there was a clear prosodic boundary between the verb and final NP in the right-dislocated sentences but not in the transitive sentences. This was attested by a significant preboundary syllable lengthening on the last syllable of the novel verb (e.g., *fome*) preceding the final NP (e.g., "*le garçon*" [the boy]) (M_{trans} = 444 ms vs. M_{disloc} = 633 ms), $t(15) = 12.91$, $p < .001$, and an important pitch drop between the max pitch observed on the verb minus the max pitch observed on the first vowel of the final NP in the right-dislocated sentences compared with the same segments in the transitive sentences ($M_{\text{trans}} = -45$ Hz vs. $M_{\text{disloc}} = -151$ Hz), $t(15) = 5.27$, $p < .001$. As in Experiment 1, there was no pause between the verb and postverbal NP.

In a pilot experiment using the same procedure described for the pilot of Experiment 1, naive French adults (N = 10) were asked to decide who was performing the action in each of these test sentences; they interpreted the transitive and dislocated sentences correctly 92% of the time.

Procedure

The procedure included five items: one practice item involving a familiar intransitive verb ("*marcher*" [to walk]) common to all participants and four novel verb test items (*fomer, daser, raner,* and *nuver*) presented in one of the three experimental conditions (transitive, right-dislocated, or intransitive). Each item included two 8-s trials in which a pair of video events was presented together with the appropriate soundtrack for the condition.

To introduce toddlers to the task, the procedure began with the practice item involving the familiar intransitive verb "*marcher*" (to walk). The target video showed a man walking (one-participant action), and the distractor video showed a different man carrying another man (two-participant action). In this practice trial, all participants were asked to look toward the one who was walking. This practice item served to show children that in this experiment only one of the two videos they saw matched the soundtrack they heard. The side of the target video (left or right) was counterbalanced across participants.

Each item started with an inspection period to provide toddlers with enough time to inspect each of the videos individually on each side of the television screen (8 s for each video). Then, 500 ms later, both videos disappeared and a sentence containing the verb was presented during a 5-s blank-screen interval (e.g., "Hey, look! He$_i$ will fome, the boy$_i$."). Next, the two videos appeared side by side on the screen for 8 s and at the same time participants heard the test sentence repeating the verb twice (e.g., "Do you see that? He$_i$ is foming, the boy$_i$! Look! He$_i$ is foming, the boy$_i$."). Each test phase was repeated twice. Thus, for each item, participants heard a total of six repetitions of the target word (four repetitions while watching the two videos side by side and two repetitions during the blank-screen interval with no videos on the screen). Fig. 6 illustrates the time course of presentation of each trial in Experiment 2.

The side of the screen on which the test videos appeared was counterbalanced within participants. For half of the items, a given participant saw the one-participant action on the left and saw the two-participant action on the right, and for the other half it was the reverse. The order of presentation of the novel verb items was random. Depending on condition, toddlers heard the four novel verbs in transitive sentences, in right-dislocated sentences, or in intransitive sentences.

Note that whereas Experiment 1 used only one pair of novel action videos and tested children with only one novel verb "*daser,*" in Experiment 2 we used four novel verbs together with four pairs of

Fig. 6. Time course of trials presentation in Experiment 2.

videos. We added more trials in Experiment 2 to have more power in the experiment (and because it was feasible given that the learning phase was much shorter in Experiment 2 than in Experiment 1, which had the dialogues before the test trials).

Data processing and analysis

In this experiment, during the test phase, participants listened to different sound files depending on the condition to which they were assigned. Similar to Experiment 1, our prediction was that looking times toward the two-participant action would be influenced by the type of sentences that participants heard. To assess these differences, we conducted two analyses as in Experiment 1. The first analysis looked at the time course of looks toward the two-participant action; we conducted three cluster-based permutation analyses comparing conditions pairwise to identify time windows where a significant difference between conditions occurred. The second analysis compared the proportion of looks averaged across conditions.[4] Both analyses were conducted on a total of 264 valid trial items

[4] Similarly to Experiment 1, we used the model specified by in R as Prop_to_2P ~ Condition + (1 | Participant). Since a model including a random slope condition for each participant did not converge.

(corresponding to the average of the valid test trials, i.e., trials for which there is less than 25% missing data)—thus, on average, 3.6 trial items per participant.

Hypotheses

Following previous studies (e.g., Yuan & Fisher, 2009; Yuan et al., 2012), we expected children in the transitive condition to look reliably longer toward the two-participant action than children in the intransitive condition. If presenting a referential context (our critical manipulation) together with the syntactic context of a verb provides cues to the verb's semantic content, helping children to use the prosodic information of right-dislocated sentences, children in the right-dislocated condition should look less toward the two-participant action than children in the transitive condition.

Results

Time course of eye movements to the two-participant action

Fig. 7A shows the time course of eye movements toward the two-participant action across conditions.

As can be seen in Fig. 7, toddlers in all three conditions tended to look more toward the two-participant action right after the beginning of the trial. Toddlers in the transitive condition (blue curve) showed the largest preference toward the two-participant action and looked more toward the two-participant action during the entire test phase. Toddlers in the intransitive condition (green curve) increased their looks toward the one-participant action as soon as they heard the first repetition of the critical verb and then remained around chance level (.50) until the end of the trial. Crucially, we can observe that toddlers in the right-dislocated sentences initially behaved as toddlers in the transitive group and looked more toward the two-participant action during the first repetition of the target word. However, from the second repetition, they increased their looks toward the one-participant action and behaved more like children in the intransitive condition.

The cluster-based analysis found a significant time window where the proportion of looks toward the two-participant action was significantly different between toddlers in the transitive condition and toddlers in the right-dislocated condition (Fig. 7B), from 6400 ms until the end of the test trial ($p < .01$) (corresponding to the second repetition of the novel verbs). When we compared the proportion of looks toward the two-participant action between toddlers in the right-dislocated condition and toddlers in the intransitive condition, a significant time window was found between 2100 and 3500 ms ($p < .05$), which coincides with the first repetition of the novel verbs (Fig. 7C). Finally, the cluster-based analysis found a significant time window where the proportion of looks toward the two-participant action was significantly different between toddlers in the transitive condition and toddlers in the intransitive condition (Fig. 7D), from 4500 ms until the end of the trial ($p < .001$).

Proportions of overall looking times to the two-participant event across conditions

Because the effect between conditions in the cluster-based analysis appeared at different time windows, we performed our second analysis comparing average proportion of looks toward the two-participant event across conditions on the whole duration of the trials (8 s). As presented in Fig. 8, looking times toward the two-participant action were modulated by condition, $\chi^2(3) = 6.98$, $p < .001$.

We replicated previous studies using the same procedure (e.g., Yuan et al., 2012); children in the transitive condition looked reliably longer at the two-participant action than children in the intransitive condition ($\beta = 0.43$, $z = 4.33$, $p < .001$). Critically, children in the right-dislocated condition looked reliably less at the two-participant action than children in the transitive condition ($\beta = -0.23$, $z = -2.26$, $p < .05$), yet they looked reliably more than children in the intransitive condition ($\beta = 0.20$, $z = 4.03$, $p < .05$).

Taken together, these results show that toddlers' looking preferences toward the two-participant action was affected by the type of sentence in which they heard the novel verbs. Toddlers who listened to transitive sentences looked longer at the two-participant action than toddlers who listened to the same novel verbs in right-dislocated sentences or in intransitive sentences. Importantly, toddlers in the right-dislocated condition were able to integrate the information presented by the visual scenes

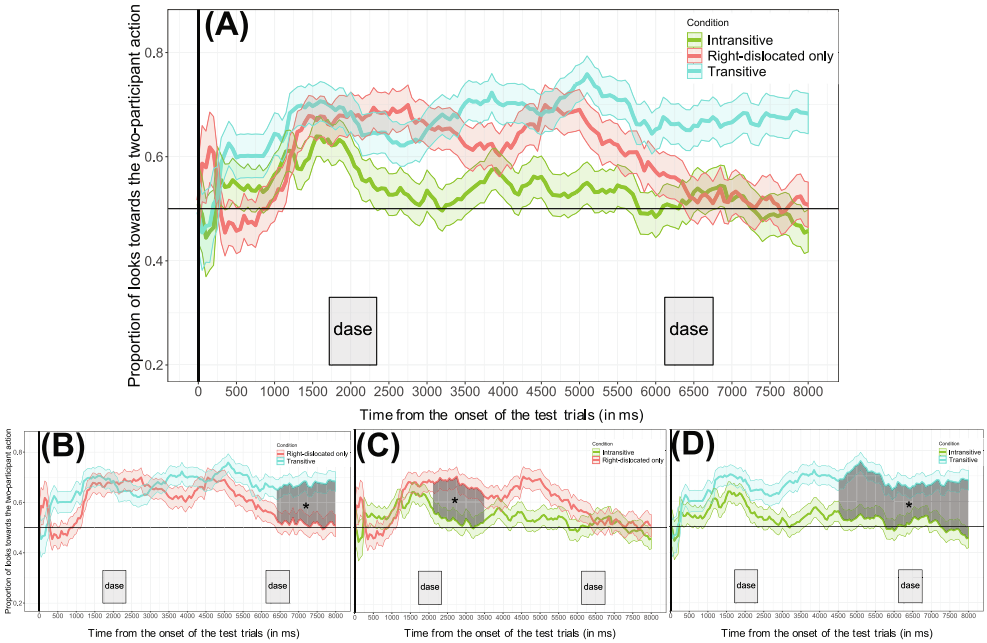

Fig. 7. (A) Proportions of looks toward the two-participant action, time-locked to the onset of the test trials (vertical black line), for toddlers in the transitive condition (blue curve), the right-dislocated condition (red curve), and the intransitive condition (green curve). Nonparametric cluster-based permutations (Maris & Oostenveld, 2007) performed on the whole duration of the test trials (8 s) revealed significant differences between conditions (time windows indicated by the black shaded area). (B) The transitive and right-dislocated conditions differed from each other from the second repetition of the novel verbs (~6400 ms after the onset of the test trials until the end of the trials). (C) The intransitive and right-dislocated conditions differed from each other from the first repetition of the novel verbs (from 2100 ms until 3500 ms after the beginning of the test trials). (D) The transitive and intransitive conditions differed from each other slightly after the offset of the first sentence in the test trials (from 4500 ms after the beginning of the test trials until the end of the trials). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

to exploit the prosodic information of the right-dislocated sentences and to guide their interpretation of the novel verbs, behaving differently from toddlers in the transitive condition.

Discussion

The results obtained here provide evidence that providing referential information concurrently with a novel verb's syntactic context helps 28-month-olds to interpret right-dislocated sentences differently from transitive sentences.

In the current experiment, toddlers who listened to a novel verb in right-dislocated sentences such as "*Il$_i$ fome, le garçon$_i$*" (i.e., meaning "The boy is foming"), while watching a one-participant action versus a two-participant action, looked reliably less toward the two-participant action than toddlers who listened to a novel verb in transitive sentences such as "*Il$_i$ fome le garçon$_k$*" (i.e., meaning "someone is foming the boy"). Thus, observing possible referential scenes provided cues to the novel verb's semantic content and might have helped children to correctly parse right-dislocated sentences. In other words, it is possible that by giving toddlers a forced choice (either Video A or Video B, so only two hypotheses to match the meaning of the novel verb) at the same time as they were processing the sentences, we reduced the cognitive load associated with the interpretation of novel verbs appearing in right-dislocated sentences. Therefore, this situation might have helped children to bring out less

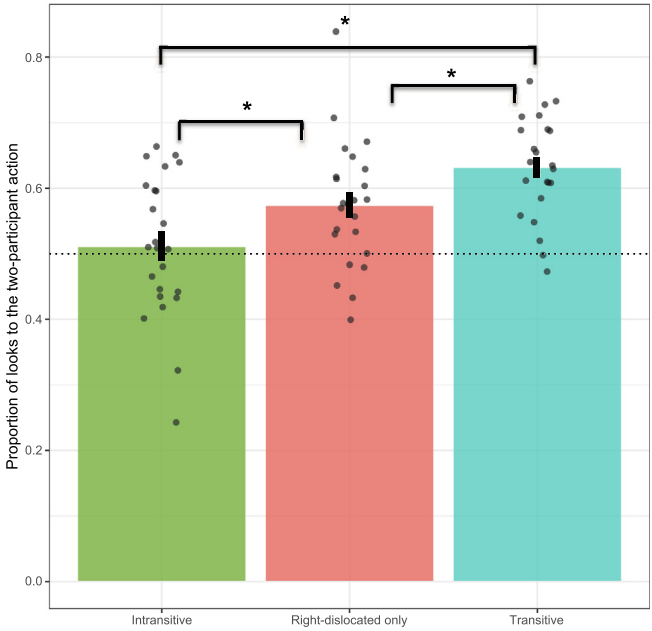

Fig. 8. Proportions of looks toward the two-participant action averaged across the whole trial for participants in the intransitive condition (green; left column), the right-dislocated condition (red; middle column), and the transitive condition (blue; right column). Error bars represent the standard error of the mean. Dots represent individual data points. Asterisks indicate significant differences between conditions.

frequent or less automatic strategies to interpret right-dislocated sentences with novel verbs, using the strategy based on prosody rather than the strategy based on the number of NPs.

It is important to note, however, that toddlers behaved differently when processing intransitive and right-dislocated sentences despite the fact that both sentence types were supporting an intransitive interpretation of the novel verbs. Children exposed to right-dislocated sentences showed, on average, a greater proportion of looks toward the two-participant event than children exposed to intransitive sentences (Fig. 8). There are two possible interpretations of this difference. One is that children in the right-dislocated condition were confused, did not reach the correct intransitive interpretation of the novel verb, and thus behaved somewhere in between the two critical conditions. We think that this interpretation is unlikely because in this kind of experimental design, when toddlers are exposed to a neutral audio featuring no novel verb (e.g., "What's happening? Look here!"), they do not show any significant preference for either of the two videos on the screen (see, e.g., baseline/neutral/control condition in Yuan & Fisher, 2009, and Yuan et al., 2012). So, confusion in this kind of experiment would have surfaced no preference for either of the two novel actions during the test phase, which was not the case in our right-dislocated condition. Instead, what we observed is that participants in the right-dislocated condition initially behaved like participants in the transitive condition and showed a significant preference for the two-participant action, a pattern of results that is consistent with what we observed in the right-dislocated-only condition in Experiment 1. The second possible interpretation (which we think is more likely) to explain the pattern of results we observed is that the difference we observed between the right-dislocated and intransitive conditions reflects a difference of processing rather than a difference of interpretation. As can be observed in Fig. 7C, in the first repetition of the novel verb during the test phase, toddlers in the right-dislocated condition looked more toward the two-participant action than toddlers in the intransitive condition before showing similar-looking behavior by the second repetition of the novel verb. This suggests that children took longer to reach the correct interpretation of right-dislocated sentences, possibly because the

presence of the two NPs in the right-dislocated sentences made these sentences harder to interpret than simple intransitive sentences.

In sum, children exposed to right-dislocated sentences did not interpret these sentences as transitive when presented with additional referential information. In addition, the time course analysis of their gaze behavior suggests that they eventually reached the correct intransitive interpretation of these right-dislocated sentences, although additional research would be needed to provide a definite answer about their final interpretation.

General discussion

In two experiments, we showed that 28-month-olds were able to adjust their parsing strategy depending on the context. In impoverished learning situations where a novel verb is presented solely in right-dislocated sentences ("He_i is VERBing, the boy_i," meaning "The boy is VERBing") and without referential support, children interpreted the sentence based on the number of NPs (someone is VERBing the boy). Yet, when they were provided with additional information about the syntactic contexts (Experiment 1) or the referential context (Experiment 2) of the novel verb, children could successfully use the prosodic information as a cue to depart from an incorrect transitive interpretation of the verb.

How did the context influence children's parsing strategy? We suggest that toddlers are able to weigh the plausibility of different information sources during language processing. When listening to right-dislocated sentences, two parsing strategies are available to children: one based on the number of NPs in the sentence (leading to a transitive syntactic structure) and another based on the prosodic information (leading to an intransitive syntactic structure). When children have no information about the novel verb, they prefer to rely on the number of NPs in the sentence because that is the parsing strategy that most often applies for sentences containing two NPs, where the first NP is interpreted as the agent of the action and the second one is interpreted as the patient of the action, as in transitive sentences. However when they have additional evidence about the verb's intransitivity (through its syntactic or semantic/referential context), the parse resulting from the integration of prosodic information became more plausible because it was compatible with the linguistic expectations that children had built about the novel verb.

This interpretation of our results follows recent work showing that adults and older children can flexibly rely on different linguistic cues depending on their reliability (e.g., Beretti, Havron, & Christophe, 2020; Fine, Jaeger, Farmer, & Qian, 2013; Gibson et al., 2013; Yurovsky et al., 2017). For instance, in Yurovsky et al. (2017), preschoolers were exposed to a speaker who always uttered either semantically plausible sentences or semantically implausible sentences blurred in brown noise. At test, children heard implausible sentences such as "I had carrots and bees for dinner." Children who heard the speaker talking about many implausible events understood the sentence literally, whereas the other group of children who were expecting plausible semantic sentences preferred to alter the perceptual information to reach a more plausible content such as "I had carrots and peas for dinner." These recent results suggest that children can flexibly adapt their interpretations of sentences depending on the respective reliability of different linguistic cues (here the perceptual syntactic input and the semantic content). Our study extends these findings; we manipulated the linguistic expectations for a novel verb (increasing the probability that the verb is intransitive) and showed that even 28-month-olds are able to flexibly rely on the signal (i.e., use prosody) to interpret sentences depending on their expectations.

The ability to flexibly attend to different linguistic cues might be extremely important for toddlers during language acquisition. In particular, because perception is inherently uncertain, being able to rely on expectations about the likely syntactic structures to be used, as we showed, or more general expectations about what a speaker intends to say (Gibson et al., 2013; Yurovsky et al., 2017) would help children to select the most likely interpretation for a sentence in situations of uncertainty.

Yet, we note that there may be an alternative explanation for the difference between our results and previous studies with right-dislocated sentences, one that relates to task difficulty. It could be that children, although capable of understanding right-dislocated sentences, are unable to deploy this knowledge consistently when the context places high demands on the parsing system such as the

presence of a novel verb in right-dislocated sentences without referential support, thereby making them rely on simpler heuristics. Providing additional support, such as a referential scene, or more syntactically diverse sentences containing the verb, as in the two experiments presented here, could have helped children to consistently apply their knowledge of right-dislocated sentences and thus depart from an incorrect interpretation of the verb.

At any rate, this study highlights the interaction between the developing processing abilities of children and the acquisition of word meanings. Children learn words in part from the utterances they hear. In fact, a rich literature documents that children use their syntactic knowledge to assign meanings to words (e.g., Arunachalam & Waxman, 2010; Brusini, Dehaene-Lambertz, Dutat, Goffinet & Christophe, 2016; de Carvalho et al., 2019; Naigles, 1990; Waxman and Markow, 1995; Yuan & Fisher, 2009). Thus, which meaning children assign to words will depend on their representation of the structure of the sentence, which in turn will depend on children's parsing abilities. As we showed here, children's parsing strategy will vary depending on the reliability of linguistic cues available to them. This suggests that failure to parse a sentence in an adult-like fashion might not necessarily reflect the immaturity of children's parsing system but rather might be indicative of what cues children consider reliable in that context.

CRediT authorship contribution statement

Alex Carvalho: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Visualization, Project administration, Funding acquisition, Writing - original draft. **Isabelle Dautriche:** Conceptualization, Methodology, Formal analysis, Visualization, Funding acquisition, Writing - review & editing. **Anne-Caroline Fiévet:** Resources. **Anne Christophe:** Supervision, Conceptualization, Methodology, Project administration, Funding acquisition, Writing - review & editing.

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References

Arunachalam, S. (2013). Two-year-olds can begin to acquire verb meanings in socially impoverished contexts. *Cognition, 129*, 569–573.

Arunachalam, S., & Dennis, S. (2019). Semantic detail in the developing verb lexicon: An extension of Naigles and Kako (1993). *Developmental Science, 22* e12697.

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*, 417–425.

Arunachalam, S., Syrett, K., & Chen, Y. (2016). Lexical disambiguation in verb learning: Evidence from the conjoined-subject intransitive frame in English and Mandarin Chinese. *Frontiers in Psychology, 7*. https://doi.org/10.3389/fpsyg.2016.00138.

Arunachalam, S., & Waxman, S. R. (2010). Meaning from syntax: Evidence from 2-year-olds. *Cognition, 114*, 442–446.

Beretti, M., Havron, N., & Christophe, A. (2020). Four- and 5-year-old children adapt to the reliability of conflicting sources of information to learn novel words. *Journal of Experimental Child Psychology, 200* 104927.

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*, 39–53.

Boersma, P., & Weenink, D. (2020). *Praat: Doing phonetics by computer* [computer program]. *Retrieved from* http://www.praat.org/.

Brusini, P., Dehaene-Lambertz, G., Dutat, M., Goffinet, F., Christophe, A. (2016). ERP evidence for on-line syntactic computations in 2-year-olds. Developmental Cognitive Neuroscience, 19, 164-173.

Dautriche, I. (2012). *The role of prosody in toddlers' interpretation of verbs' argument structure*. Ecole normale supérieure: Université Paris Descartes.

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*, 1168–1180.
Dautriche, I., Swingley, D., & Christophe, A. (2015). Learning novel phonological neighbors: Syntactic category matters. *Cognition, 143*, 77–86.
de Carvalho, A., Babineau, M., Trueswell, J. C., Waxman, S. R., & Christophe, A. (2019). Studying the real-time interpretation of novel noun and verb meanings in young children. *Frontiers in Psychology, 10*. https://doi.org/10.3389/fpsyg.2019.00274.
de Carvalho, A., Dautriche, I., & Christophe, A. (2016). Preschoolers use phrasal prosody online to constrain syntactic analysis. *Developmental Science, 19*, 235–250.
de Carvalho, A., Dautriche, I., Lin, I., & Christophe, A. (2017). Phrasal prosody constrains syntactic analysis in toddlers. *Cognition, 163*, 67–79.
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*, 319–332.
de Carvalho, A., Lidz, J., Tieu, L., Bleam, T., & Christophe, A. (2016). English-speaking preschoolers can use phrasal prosody for syntactic parsing. *Journal of the Acoustical Society of America, 139*, EL216–EL222.
De Cat, C. (2007). *French dislocation: Interpretation, syntax, acquisition*. New York: Oxford University Press.
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*, 1–12.
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.
Fernald, A., Zangl, R., Portillo, A. L., & Marchman, V. A. (2008). Looking while listening: Using eye movements to monitor spoken language comprehension by infants and young children. In I. A. Sekerina, E. M. Fernández, & H. Clahsen (Eds.), *Language acquisition and language disorders, Vol. 44: Developmental psycholinguistics: On-line methods in children's language processing* (pp. 97–135). Amsterdam: John Benjamins.
Fernandes, K. J., Marcus, G. F., Di Nubila, J. A., & Vouloumanos, A. (2006). From semantics to syntax and back again: Argument structure in the third year of life. *Cognition, 100*, 810–820.
Fine, A. B., Jaeger, T. F., Farmer, T. A., & Qian, T. (2013). Rapid expectation adaptation during syntactic comprehension. *PLoS One, 8*(10) e77661.
Fisher, C. (1996). Structural limits on verb mapping: The role of analogy in children's interpretations of sentences. *Cognitive Psychology, 31*, 41–81.
Fisher, C. (2002). Structural limits on verb mapping: The role of abstract structure in 2.5-year-olds' interpretations of novel verbs. *Developmental Science, 5*, 55–64.
Fisher, C., Jin, K., & Scott, R. M. (2020). The developmental origins of syntactic bootstrapping. *Topics in Cognitive Science, 12*, 48–77.
Gentner, D. (1982). Why nouns are learned before verbs: Linguistic relativity versus natural partitioning. In S. Kuczaj (Ed.), *Language development, Vol.2: Language, thought, and culture* (pp. 301–334). Hillsdale, NJ: Lawrence Erlbaum.
Gentner, D., & Boroditsky, L. (2001). Individuation, relativity, and early word learning. In M. Bowerman & S. Levinson (Eds.), *Language acquisition and conceptual development* (pp. 215–256). Cambridge, UK: Cambridge University Press.
Gertner, Y., & Fisher, C. (2012). Predicted errors in children's early sentence comprehension. *Cognition, 124*, 85–94.
Gibson, E., Bergen, L., & Piantadosi, S. T. (2013). Rational integration of noisy evidence and prior semantic expectations in sentence interpretation. *Proceedings of the National Academy of Sciences of the United States of America, 110*, 8051–8056.
Gillette, J., Gleitman, H., Gleitman, L., & Lederer, A. (1999). Human simulations of vocabulary learning. *Cognition, 73*, 135–176.
Gleitman, L. (1990). The structural sources of verb meanings. *Language Acquisition, 1*, 3–55.
Gleitman, L., Cassidy, K., Nappa, R., Papafragou, A., & Trueswell, J. (2005). Hard words. *Language Learning and Development, 1*, 23–64.
Gleitman, L. R., & Trueswell, J. C. (2020). Easy words: Reference resolution in a malevolent referent world. *Topics in Cognitive Science, 12*, 22–47.
Grimshaw, J. (1994). Lexical reconciliation. Lingu, 92(C), 411–430. http://doi.org/10.1016/0024-3841(94)90348-4.
Hahn, N., Snedeker, J., & Rabagliati, H. (2015). Rapid linguistic ambiguity resolution in young children with autism spectrum disorder: Eye tracking evidence for the limits of weak central coherence. *Autism Research, 8*, 717–726.
Hawthorne, K., & Gerken, L. (2014). From pauses to clauses: Prosody facilitates learning of syntactic constituency. *Cognition, 133*, 420–428.
Huang, Y. T., & Arnold, A. R. (2016). Word learning in linguistic context: Processing and memory effects. *Cognition, 156*, 71–87.
Huang, Y. T., Leech, K., & Rowe, M. L. (2017). Exploring socioeconomic differences in syntactic development through the lens of real-time processing. *Cognition, 159*, 61–75.
Huang, Y. T., Zheng, X., Meng, X., & Snedeker, J. (2013). Children's assignment of grammatical roles in the online processing of Mandarin passive sentences. *Journal of Memory and Language, 69*, 589–606.
Jaeger, F. T. (2010). Redundancy and reduction: Speakers manage syntactic information density. *Cognitive Psychology, 61*, 23–62.
Landau, B., & Gleitman, L. (1985). *Language and experience: Evidence from the blind child*. Cambridge, MA: Harvard University Press.
Levin, B., & Hovav, M. R. (1995). *Unaccusativity: At the syntax-semantics interface*. Cambridge, MA: MIT Press.
Levy, R. (2008). Expectation-based syntactic comprehension. *Cognition, 106*, 1126–1177.
Lidz, J., Gleitman, H., & Gleitman, L. (2003). Understanding how input matters: Verb learning and the footprint of universal grammar. *Cognition, 87*, 151–178.
Lidz, J., Williams, A., & Perkins, L. (2017, November). Conceptual correlates of transitivity in early verb learning. Paper presented at the 42nd Boston University Conference on Language Development, Boston.
Maris, E., & Oostenveld, R. (2007). Nonparametric statistical testing of EEG- and MEG-data. *Journal of Neuroscience Methods, 164*, 177–190.
Massicotte-Laforge, S., & Shi, R. (2015). The role of prosody in infants' early syntactic analysis and grammatical categorization. *Journal of the Acoustical Society of America, 138*, 441–446.

Massicotte-Laforge, S., & Shi, R. (2020). Is prosodic information alone sufficient for guiding early grammatical acquisition? *Journal of the Acoustical Society of America, 147*, EL295–EL300.
Matsuo, A., Kita, S., Shinya, Y., Wood, G. C., & Naigles, L. (2012). Japanese two-year-olds use morphosyntax to learn novel verb meanings. *Journal of Child Language, 39*, 637–663.
Messenger, K., & Fisher, C. (2018). Mistakes weren't made: Three-year-olds' comprehension of novel-verb passives provides evidence for early abstract syntax. *Cognition, 178*, 118–132.
Messenger, K., Yuan, S., & Fisher, C. (2015). Learning verb syntax via listening: New evidence from 22-month-olds. *Language Learning and Development, 11*, 356–368.
Naigles, L. (1990). Children use syntax to learn verb meanings. *Journal of Child Language, 17*, 357–374.
Naigles, L. (1996). The use of multiple frames in verb learning via syntactic bootstrapping. *Cognition, 58*, 221–251.
Naigles, L., Bavin, E., & Smith, M. (2005). Toddlers recognize verbs in novel situations and sentences. *Developmental Science, 8*, 424–431.
Naigles, L. G., Fowler, A., & Helm, A. (1992). Developmental shifts in the construction of verb meanings. *Cognitive Development, 7*, 403–427.
Naigles, L., Gleitman, H., & Gleitman, L. (1993). Children acquire word meaning components from syntactic evidence. In E. Dromi (Ed.), *Language and cognition: A developmental perspective* (pp. 104–140). Norwood, NJ: Ablex.
Naigles, L. G., & Kako, E. T. (1993). First contact in verb acquisition: Defining a role for syntax. *Child Development, 64*, 1665–1687.
Schmale, R., Cristia, A., & Seidl, A. (2012). Toddlers recognize words in an unfamiliar accent after brief exposure. *Developmental Science, 15*, 732–738.
Scott, R. M., & Fisher, C. (2009). Two-year-olds use distributional cues to interpret transitivity-alternating verbs. *Language and Cognitive Processes, 24*, 777–803.
Scott, R. M., & Fisher, C. (2012). 2.5-Year-olds use cross-situational consistency to learn verbs under referential uncertainty. *Cognition, 122*, 163–180.
Snedeker, J., & Yuan, S. (2008). Effects of prosodic and lexical constraints on parsing in young children (and adults). *Journal of Memory and Language, 58*, 574–608.
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*, 24–37.
Swingley, D., & Aslin, R. N. (2000). Spoken word recognition and lexical representation in very young children. *Cognition, 76*, 147–166.
Von Holzen, K., & Mani, N. (2012). Language nonselective lexical access in bilingual toddlers. *Journal of Experimental Child Psychology, 113*, 569–586.
Waxman, S. R., & Markow, D. B. (1995). Words as invitations to form categories: Evidence from 12- to 13-month-old infants. *Cognitive Psychology, 29*, 257–302.
Woodard, K., Pozzan, L., & Trueswell, J. C. (2016). Taking your own path: Individual differences in executive function and language processing skills in child learners. *Journal of Experimental Child Psychology, 141*, 187–209.
Yuan, S., & Fisher, C. (2009). "Really? She blicked the baby?": Two-year-olds learn combinatorial facts about verbs by listening. *Psychological Science, 20*, 619–626.
Yuan, S., Fisher, C., & Snedeker, J. (2012). Counting the nouns: Simple structural cues to verb meaning. *Child Development, 83*, 1382–1399.
Yurovsky, D., Case, S., & Frank, M. C. (2017). Preschoolers flexibly adapt to linguistic input in a noisy channel. *Psychological Science, 28*, 132–140.