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

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

## 1. 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 noun phrases in the sentence (e.g., "the girl is pushing the boy") while verbs describing a participant acting solo are instantiated in intransitive sentences featuring a single noun phrase (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, 2018; Arunachalam, Syrett, & Chen, 2016; Arunachalam & Waxman, 2010; Dautriche et al., 2014; Fisher, 2002; Fisher, Jin, & Scott, 2020; Messenger, Yuan, & Fisher, 2015; Naigles & Kako, 1993; Naigles, 1990; 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 show the same preference when the novel verb appears in an intransitive sentence structure ("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, i.e., 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 noun

phrases (NPs) in the sentence as a cue to its semantic predicate argument structure (Fisher, 2002). Although this parsing strategy is efficient in distinguishing transitive from intransitive sentence structures, it can also lead to the assignment of erroneous syntactic structures, as not all the sentences containing two noun phrases 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 gorging the girl” and in the sentence “The boy and the girl are gorging!”, since in both conditions they interpret “gorging” 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.

While 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-months-old were shown to be selective in their application of parsing strategies when interpreting right-dislocated sentences (e.g., “*Il<sub>i</sub> dort, le lapin<sub>i</sub>*” – It<sub>i</sub> is sleeping, the bunny<sub>i</sub>). 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 noun phrases, because in this case “the bunny” is co-referring to the pronoun “It.”<sup>1</sup>. Thus right-dislocated sentences can contain an intransitive verb between two noun phrases, and describe an action with a single participant. 28-month-olds correctly interpreted right-dislocated sentences containing familiar verbs (e.g., “*Il<sub>i</sub> mange, le lapin<sub>i</sub>*” – It<sub>i</sub> is eating, the rabbit<sub>i</sub>, as meaning ‘the rabbit is eating’), but failed to assign the correct parse to right-dislocated sentences containing a novel verb (e.g., “*Il<sub>i</sub> dase, le garçon<sub>i</sub>*” – He<sub>i</sub> is *dasing*, the boy<sub>i</sub>). Instead, toddlers behaved exactly as if they had heard a transitive sentence

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<sup>1</sup> Note that a similar type of prosodic structure can be observed in English when we utter a sentence like “Let’s eat, children!” in which hopefully *children* will not be the patient of the action (to eat), but rather the agent.

(e.g., “*Il<sub>i</sub> dase le garçon<sub>k</sub>*” – He<sub>i</sub> is dasing the boy<sub>k</sub>), 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 children, while able to understand right-dislocated sentences containing familiar verbs, 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 noun phrases in the sentence (i.e., assuming for instance that a novel verb appearing in a sentence containing two noun phrases 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 suggest that adults choose the most plausible interpretation of a sentence depending on the context in which they are, even when this entails altering the sentence structure (Gibson, Bergen, & Piantadosi, 2013; Jaeger, 2010; Levy, 2008, see also Naigles, Gleitman, & Gleitman, 1993; Naigles, Fowler, & Helm, 1992). 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 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, 2016 for a similar experiment with preschoolers). The question that arises is: Can toddlers process language in a similarly flexible way, and deploy different parsing strategies depending on how plausible they are made by the context? Such a flexibility is a critical component of spoken language

comprehension as 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 this, 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 (e.g., *Il<sub>i</sub> VERB, le garçon<sub>i</sub>* - ‘He<sub>i</sub> is VERBing, the boy<sub>i</sub>’, 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<sub>i</sub> eats, the bunny<sub>i</sub>’, meaning ‘the bunny is eating’)<sup>2</sup>. In this study, children fail to accurately interpret sentences for which they have an 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), that they reach when interpreting familiar verbs, or a transitive one (based on the number of NPs in the sentence), that 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 both in transitive and in intransitive frames (‘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 be used both in transitive frames containing two noun phrases (e.g., ‘the boy is eating an apple’) and in intransitive frames containing only one noun phrase (e.g., ‘the boy

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<sup>2</sup> Additionally, 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, Lidz, Tieu, Blean, & Christophe, 2016; de Carvalho, He, Lidz, & Christophe, 2019; Hawthorne & Gerken, 2014; Massicotte-Laforge & Shi, 2015, 2020; Snedeker & Yuan, 2008), supporting the idea that 28-month-old children have no problem to use prosody, in general, to comprehend sentences.

is eating') or even in right-dislocated sentences that they may have already heard in their everyday lives (about 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 since 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, since they had only heard that novel verb repeated several times in sentences containing 2 NPs. In this uncertain situation, toddlers might have preferred to rely on the parsing strategy that most often applies for sentences containing 2 NPs where the first NP is interpreted as the agent of the action and the second one as the patient, 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 suggest that children can gain information about the meaning of the verb by observing the *set* of syntactic structures in which it appears (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<sub>i</sub> dase, le garçon<sub>i</sub>. Ah bon, Il dase?* - He<sub>i</sub> is dasing, the boy<sub>i</sub>. Really, he is dasing?). We hypothesized that simply showing toddlers that the novel verb could also appear in intransitive frames (thus 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. While previous research show 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 the referential contexts (see also Grimshaw, 1994). This time, toddlers heard the novel verb in right-dislocated sentences while viewing two simultaneously presented events: One event showing a person performing a self-generated action (a one-participant action) and another video showing a person acting on another (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 noun phrases).

In both experiments we expected that when children interpret the novel verb as transitive, thus inferring that the verb's meaning involves two participant roles, they should look more towards the two-participant action video than the one-participant video. In contrast, children who interpret the novel verb as intransitive, thus inferring that the verb's meaning involves one participant role, would not show preference for any of the event, as the intransitive verb could



refer both to the one-participant event or to a sub-component of the two-participant action (Fernandes, Marcus, Di Nubila, & Vouloumanos, 2006; Fisher, 2002; Yuan & Fisher, 2009). Yet following previous studies (e.g., Arunachalam & Dennis, 2018; Arunachalam & Waxman, 2010; Dautriche et al., 2014; Fisher, 2002; Matsuo, Kita, Shinya, Wood, & Naigles, 2012; Messenger et al., 2015; Naigles & Kako, 1993; Naigles, 1990; Suzuki & Kobayashi, 2017; Yuan & Fisher, 2009; Yuan et al., 2012), we predicted that participants in the intransitive condition will therefore behave significantly different from participants in the transitive condition.

## 2. 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 and intransitive-only (see Figure 1). In each dialogue condition, toddlers listened to a total of 8 sentences containing a novel verb (i.e., *daser*). In the transitive+intransitive condition they heard 4 transitive sentences and 4 intransitive sentences in alternation; in the right-dislocated+intransitive condition they heard 4 right-dislocated sentences and 4 intransitive sentences in alternation; in the right-dislocated-only condition they heard 8 right-dislocated sentences and in the intransitive-only condition they heard 8 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 both in transitive and intransitive frames, we

expect that toddlers exposed to the dialogues in the transitive+intransitive condition should still be able to interpret the novel verb as transitive and referring to a two-participants 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 predict 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, therefore making it easier for toddlers to rely on the prosodic information to parse the right-dislocated sentence. Since 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 is predicted from previous studies (e.g., Arunachalam & Dennis, 2018; 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 at a component of the two-participant caused-motion event (e.g., focusing their attention at the agent of the two participants action, see the *Structure Mapping Account* – 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 expect 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 towards the two-participants action during the test. As established in many previous studies (e.g., Arunachalam & Dennis, 2018; 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 expect 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 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 will 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.

## **2.1. Method**

The stimuli, data and analyses of the experiments reported in this paper are freely accessible to readers on the OSF (Open Science Framework) database through the following link:

[https://osf.io/b5yqp/?view\\_only=7b34cd9ddba94da28adc1f8958c25fab](https://osf.io/b5yqp/?view_only=7b34cd9ddba94da28adc1f8958c25fab)

### **2.1.1. Participants**

Eighty-one French 28-month-olds participated in this study (mean age = 28.0 months, range = 26.9 to 30.2; SD = 0.7; 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 thirty-six children participated in the study but were not included in the final analysis because of fussiness during the experiment (5), distraction during the dialogue phase (6), side bias (1), unusable test trials with missing eye tracking data (21),

because they were exposed to other languages than French at home (1), or because of technical problems (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).

### **2.1.2. Apparatus**

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

### **2.1.3. 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 sound tracks recorded by a female native French speaker (last author).

The procedure was similar to that of Dautriche et al., (2014) and Yuan & Fisher (2009). The experiment was composed of three blocks: practice, dialogue and test. The practice block was comprised of two practice items involving familiar verbs, one intransitive (either *danser* – to dance, or *marcher* – to walk) and one transitive (either *pousser* – to push or *porter* – to carry). These practice items consist of two 8s 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

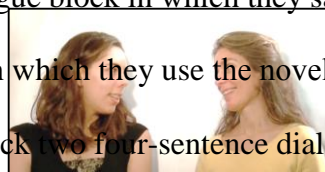
the videos. For instance, for the familiar verb “marcher” (to walk), participants saw two videos played side by side: a girl walking in one video and a girl dancing in the other video, while children heard the stimulus sentence “*Tu la vois qui marche? Regarde celle qui marche!*” - Do you see her walking? 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 seconds on the left or the 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., Figure 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 participants had the intransitive trial first (i.e., “*danser*” vs “*marcher*”) and the transitive trial second (e.g., “*pousser*” vs. “*porter*”) and half had the reverse. Within each trial, half of the participants saw the target video on the left side and the other half 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

**Dialogue phase (4 conditions)**

block, participants started the dialogue block in which they saw a dialogue between two women speaking in child-friendly speech in which they use the novel verb “*daser*” in one of four experimental conditions. In this block two four-sentence dialogue video clips of 24s separated by a



3s interval were presented in the middle of the screen. Thus, each participant was exposed to eight sentences: four transitive and four intransitive in alternation for the transitive-intransitive condition; four right-dislocated and four intransitive 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 Figure 1, for the

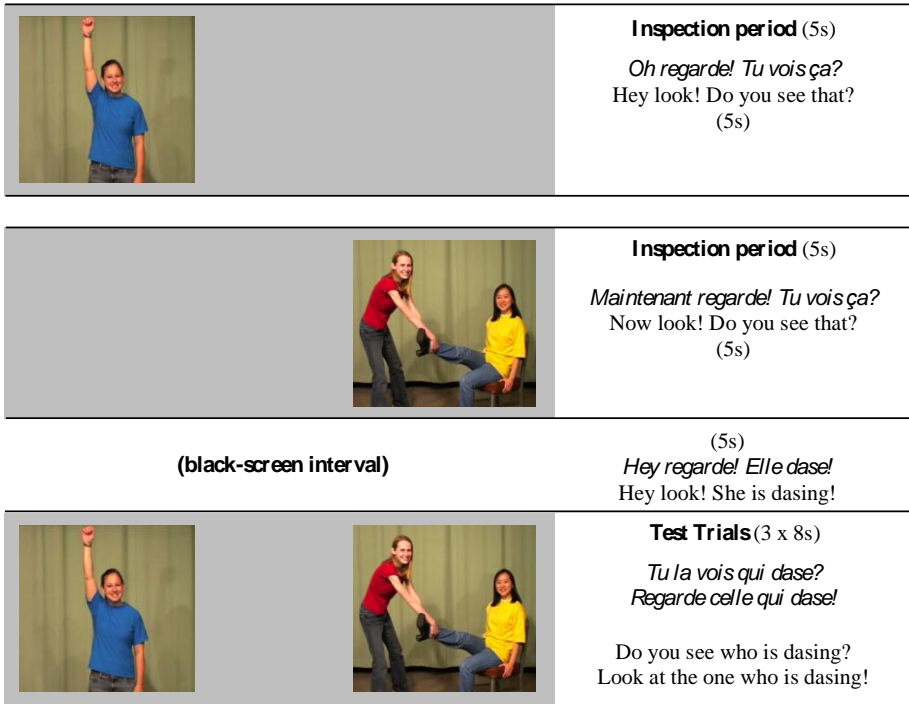
----- <b>Transitive+Intransitive</b> -----	
A: Hey! Il va <i>daser</i> le papa!	Hey! He will <i>dase</i> the dad!
B: Ah bon, il va <i>daser</i> ?	Really, he will <i>dase</i> ?
A: Oui, et en plus ils ont <i>dasé</i> les garçons.	Yeah! And they <i>dased</i> the boys!
B: C'est vrai, ils ont <i>dasé</i>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

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

**Figure 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 in two 24-s videos containing four sentences each separated by a 3-s black screen. Transitive+intransitive and right-dislocated+intransitive dialogues were composed exactly of the same words, but differed only in their prosodic structures, reflecting their different syntactic structures.

Three seconds after the end of the dialogue phase, participants started the test block. This block presented participants with two videos illustrating two novel actions. One video showed an action executed by one 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 & 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 eight seconds. 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 her dasing? Look at the one who is dasing!; see Figure 2).



**Figure 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 in a different side of the screen for 5 seconds. Then the two videos were presented simultaneously side-by-side on the screen for 8 seconds (in each of the three test trials) and participants were asked to look at the one who was “dasing”.

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

#### 2.1.4. Acoustic Analysis

Given that the transitive and the 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 acoustical 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 ( $M_{trans} = 199\text{ms}$  vs  $M_{disloc} = 621\text{ms}$ ,  $t(6) = 5.71$ ,  $p < 0.01$ ).

Additionally 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 the max pitch on the ‘-ə’ from ‘le papa’ - the daddy) was larger in right-dislocated sentences compared to transitive sentences:  $M_{trans} = -6.07\text{Hz}$  vs  $M_{disloc} = -101.15\text{Hz}$ ,  $t(3) = 13.17$ ,  $p < 0.001$ ). Note that there were no pauses between the verb and the final NP, which ensures that to differentiate the transitive from the right-dislocated sentences, toddlers had to interpret the prosodic structure of the sentences rather than just ignoring 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 would listen to a sentence (e.g., “*Elles<sub>i</sub> ont dasé, les filles<sub>i</sub>*” - “They<sub>i</sub> dased, the girls<sub>i</sub>”) and at the same time they 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 would then press the right or the left arrow on the computer keyboard to indicate their



answer. The results showed that participants interpreted transitive and right-dislocated sentences correctly over 94% of the time. That is, they chose the postverbal noun phrase (e.g., “the girls”), 94% of the time when listening to right-dislocated sentences, while they only selected that answer 6% of the time when listening to transitive sentences.

### **2.1.5. 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 1 (out of 3) valid trials. This resulted in a total of 227 valid trials ( $M = 2.8$  trials per participant).

### **2.1.6. Measurement and statistical analysis**

In this experiment, during the test phase all participants listened to the same sound files (asking them to look towards the one who was *dasing*). Our prediction was that the dialogues they heard before the test would impact their looking preference towards the two-participants action at test. Given that the looking times toward the two-participants action and toward the one-participant action are almost complementary (except for the away looking time, which was not reliably different between conditions), the dependent variable was the proportion of looking times towards the two-participants action, computed for each time bin of 50ms (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. In order to find whether there was a time-window in which children looked towards the two-participants action significantly more in one condition than another, we conducted six cluster-based permutation analyses on the entire duration of the test trials (from 0 to 8000ms) 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 et al., 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 having to select it arbitrarily. This analysis involves two steps: 1) the identification of time-windows that have a potential effect; 2) 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 proportion of looks towards the two-participants 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 to 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; and 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 towards the two-participants event for each trial in a mixed logit model with a fixed predictor Condition (4 modalities: transitive+intransitive; right-dislocated+intransitive; right-dislocated-only; intransitive-only) and a random Subject effect. The model was specified as:  $\text{Prop\_to\_2P} \sim \text{Condition} + (1 \mid \text{Participant})$  and was used on data averaged

at the trial level on the whole trial duration (such that each participant had 1 to 3 data points).

Because the dependent variable is a continuous variable in the [0; 1] interval and is a mean of non-independent samples, we used the glmmTMB package in R to model it with a beta distribution.

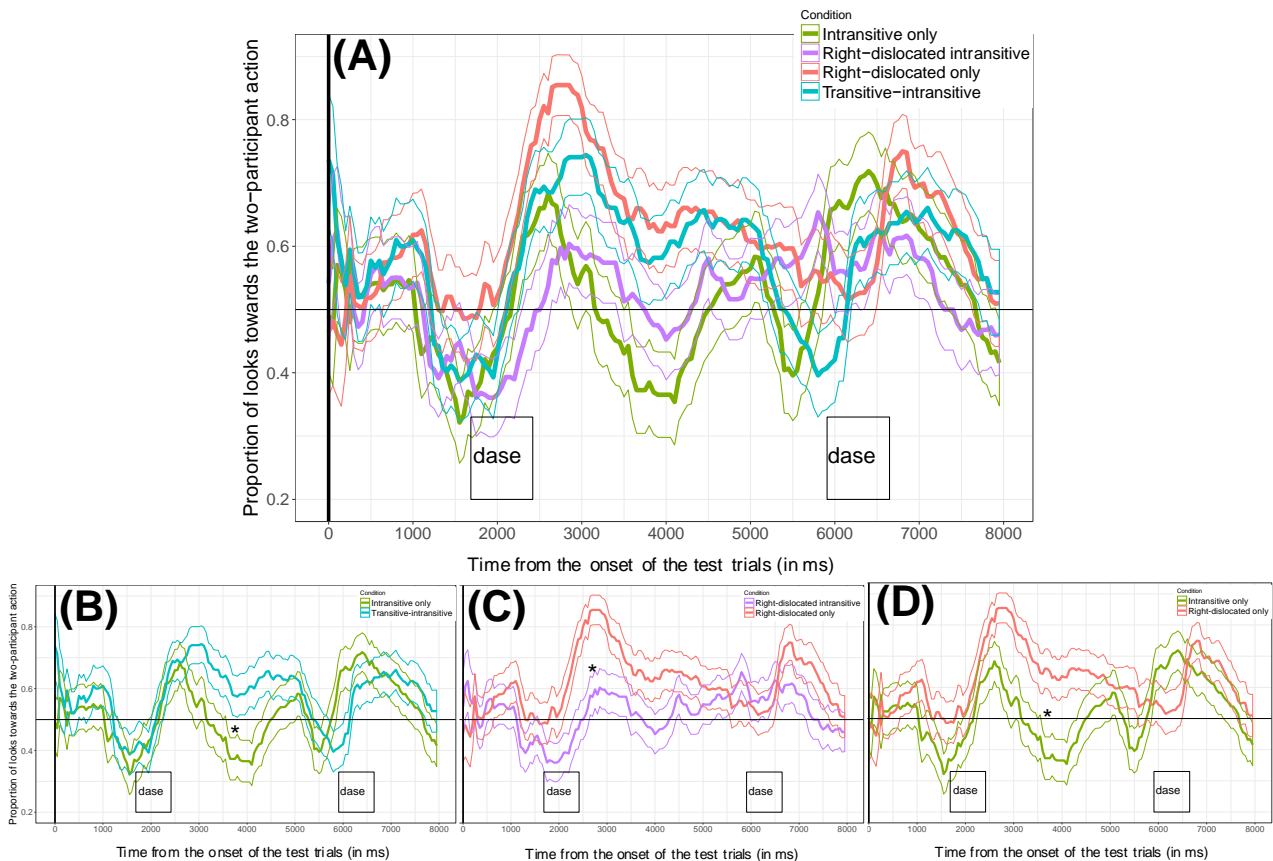
### **2.1.6. Hypotheses**

We expect 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-participants action.

## **2.2. Results**

### *Time course of eye movements to the two-participants action*

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



**Figure 3:** (A) Proportion of looks towards the two-participants action, time-locked to the onset of the test trials (vertical black line) for toddlers in the intransitive-only condition (green curve), in the right-dislocated+intransitive condition (purple curve), the right-dislocated-only condition (red curve) and in the transitive+intransitive condition (blue curve). Non-parametric cluster-based permutations (Maris & Oostenveld, 2007) performed on the whole duration of the test trials (8s) revealed significant differences between (B) the transitive+intransitive and the intransitive conditions, (C) the right-dislocated only and the right-dislocated+intransitive condition, and (D) the right-dislocated only and the intransitive conditions (all  $p$ s < .05; time windows indicated by the black shaded area). No other pair-wise comparisons were significant.

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 2600ms until 4650ms;  $p < 0.01$ ; see Figure 3-D), 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-participants event than toddlers in the right-dislocated only condition (from 2000ms until 3350ms;  $p < 0.05$ ; see Figure 3-C). Thus, toddlers who heard right-dislocated sentences in alternation with

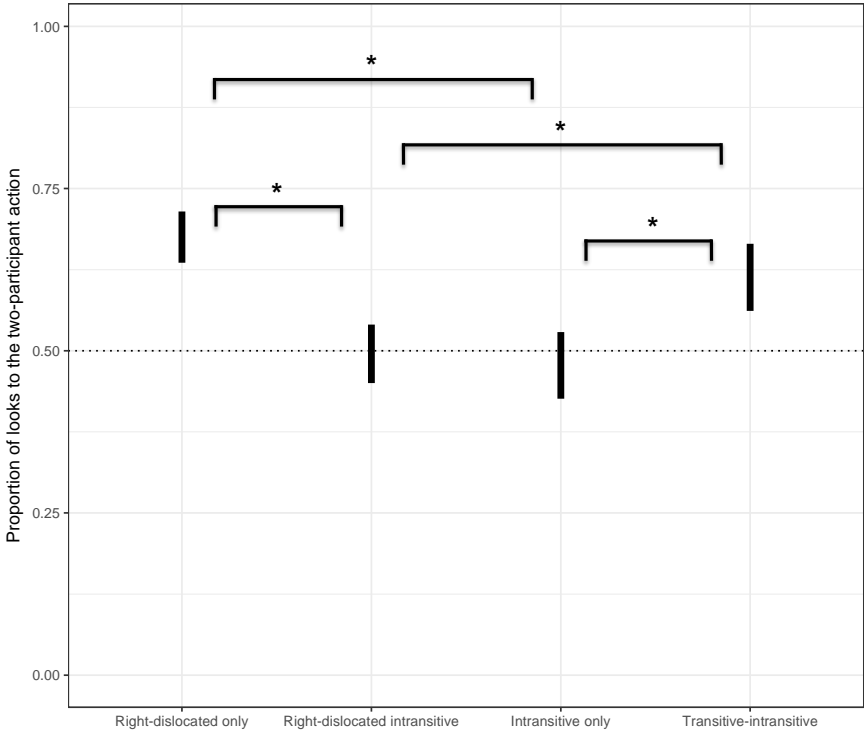
intransitive sentences did not interpret the novel verb *daser* as referring to a two-participants action, unlike toddlers who heard the novel verb only in right-dislocated sentences. This suggests that providing more information about the syntactic contexts of a novel verb helped children correctly 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 2800ms until 4700ms;  $p < 0.05$ , see Fig 3-B). 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-participants action and behave as if they had heard the novel verb in intransitive sentences only. No other pair-wise 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 since most of the previous studies using this paradigm report only the averaged looking times over the whole trial duration and not the time course of looks (e.g., Yuan & Fisher, 2009; Dautriche et al., 2014; Yuan, Fisher, & Snedeker, 2012), it is unclear whether the effect we should observe in this kind of experimental design is peaked in a specific time window (as it is usually the case in word recognition tasks involving nouns, e.g., Bion, Borovsky, & Fernald, 2013; Dautriche, Swingley, & Christophe, 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., of sizes between 1.5 to 2s), are consistent with several previous studies using this same experimental design. For instance, in Arunachalam, Escovar, Hansen, & Waxman (2013), effects of verb learning with 21-month-olds were observed

between 1.5s to 4s 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, since the effect of condition was observed between 1 and 2.5s from the first onset of the target verb. In both of these studies the effects lasted for about 1.5s. 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 (1685ms after the start of the trial) until the halfway point of the trial duration (4000ms).

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



**Figure 4.** Proportion of looks towards the two-participants action averaged on the time window starting at the onset of the target word (1685ms after the start of the trial) until half of the trial duration (4000ms), for participants in the right-dislocated-only condition (red), in the right-dislocated+intransitive condition (purple), in the intransitive-only condition (green) and in the transitive+intransitive condition (blue). Error bars represent the standard error of the mean. Dots represent individual data points.

As represented in Figure 4, looking times towards the two-participants action in that time window were affected by dialogue conditions ( $\chi^2(3) = 12.62 ; p < 0.01$ ). 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 ( $\beta = 0.75$ ;  $z = 2.83$ ;  $p < 0.01$ ) and toddlers in the right-dislocated+intransitive condition ( $\beta = -0.78$ ;  $z = -3.07$ ;  $p < 0.01$ ).

Toddlers in the transitive+intransitive condition looked more at the two-participant event than did children in the intransitive-only condition ( $\beta = 0.52$ ;  $z = 1.96$ ;  $p < 0.05$ ).

In addition, toddlers in the transitive+intransitive condition looked also reliably more toward the two-participants action than did children in the right-dislocated+intransitive condition ( $\beta = 0.52$ ;  $z = 1.96$ ;  $p < 0.05$ ). 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 ( $p > 0.1$ ).

### 2.3. Discussion

Experiment 1 shows that from 28 months old, 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<sub>i</sub> is VERBing, the baby<sub>i</sub>*') 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, therefore 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 find that these children associated the verb to 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). While this does not completely exclude the possibility of a priming effect from the intransitive sentences, as children could be still less likely to look at the two-participant action than if they were exposed to only transitive sentences, we feel 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 look 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 ( $M = 0.56$ ;  $SE = 0.03$ ) 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 lots of transitive verbs that can appear in both transitive and intransitive structures (e.g., Scott & Fisher, 2009). In the current study 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; Naigles, Bavin and Smith, 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, while 21-month-olds mistakenly interpret sentences such as “The boy and the girl are gorp-ing” 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 gorp-ing. 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 gorp-ed the girl. Really? The boy gorp-ed 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 study however, both the transitive+intransitive and the 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 can not be simply explained by the presence of disambiguating syntactic information, but rather 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. Transitive+intransitive sentences gave rise to a final transitive interpretation for the novel verb, while 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 to a two-participant action, the current study shows that when the syntactic

context is enriched with simple intransitive sentences, toddlers reach the correct interpretation of the verb. An interesting follow-up question is thus whether other sources of information could also help children 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 they 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, Gleitman, & Gleitman, 1993). Thus, observing possible referential scenes together with a novel verb may also influence toddlers' reliance on different linguistic cues and may help them to avoid certain parsing biases, because these observations would constrain the range of possible interpretations for the verb. In the present 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 with fewer candidate interpretations for the novel verb would impact their parsing strategy.

### **3. 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 since that 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 as they only need to choose the event matching the sentence they hear, rather than building a semantic representation of the verb based on the sole linguistic input they hear (as it was the case in the dialogue phase in Experiment 1).

When presented with a video of a 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's gorping him) should look more to the causal action than toddlers who listened to intransitive sentences (e.g., He is gorping, see Yuan et al., 2012). In the current experiment we aim 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 noun phrases (which leads to a transitive interpretation of the novel verb) and another one based on the prosodic information (which leads to an intransitive interpretation of the verb). Here we investigate whether introducing toddlers with 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 noun phrases). 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<sub>i</sub> fome, le garçon<sub>i</sub>* ('He<sub>i</sub> is foming, the boy<sub>i</sub>,', meaning the boy is foming), or transitive sentences such as *Il<sub>i</sub> fome le garçon<sub>k</sub>* ('He<sub>i</sub> is foming the boy<sub>k</sub>,', meaning someone else is foming the boy) while watching two videos side-by-side on a TV-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 provides cues to the verb's semantic content (thus introducing the possibility that the verb refers to a single participant event), then children in the right-dislocated condition should look less towards the two-participant action than children in the transitive condition. Additionally, 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 expect that children in the transitive condition would look reliably longer to the two-participants action than children in the intransitive condition (e.g., Yuan & Fisher, 2009; Yuan, Snedeker & Fisher, 2012).

### 3.1. Method

#### 3.1.1. Participants

Seventy-two 28-month-olds (ranging in age from 26.7 to 29.0,  $M_{\text{age}}=27.7$ ;  $SD=0.5$ ; 36 girls) participated in this experiment. All were monolingual native French speakers with less than 20% of exposure to another language. Twenty-four toddlers were randomly assigned to each of the three experimental conditions (transitive, right-dislocated, and intransitive). An additional twelve toddlers completed the experiment but they 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 ( $n = 9$ ), because they cried during the experiment ( $n = 2$ ), or because of 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).

### **3.1.2. Apparatus**

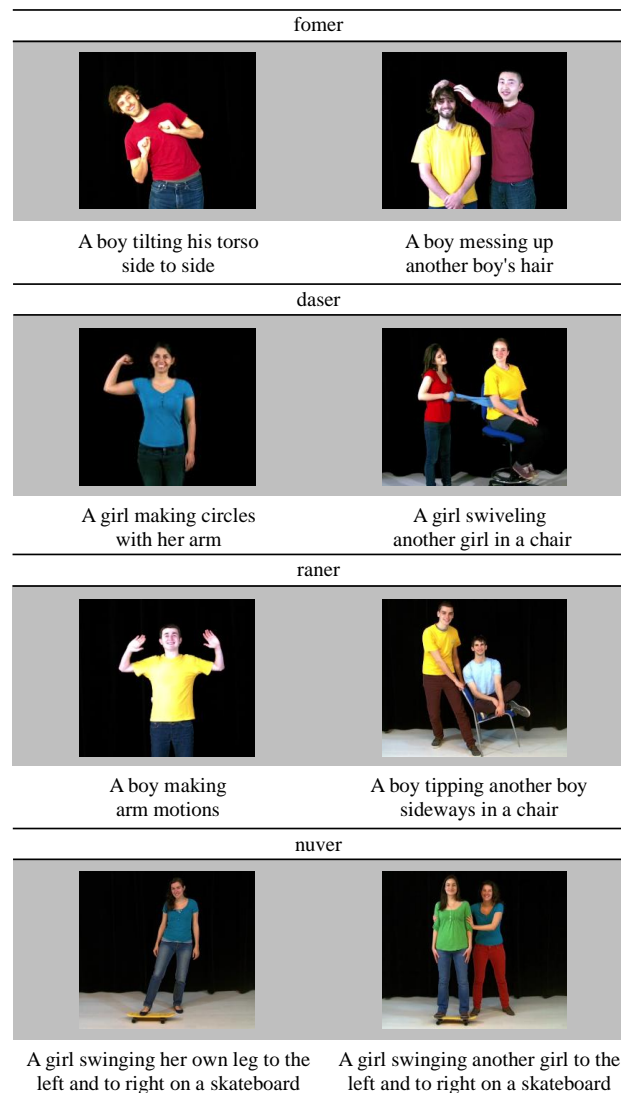
The apparatus was similar to that of Experiment 1 except that the experiment took place in a different sound-attenuated booth (IAC Acoustics) and used a 27-in television screen to present the stimuli.

### **3.1.3. 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*, *nuver*, (see Figure 5 for action descriptions).

Additionally, 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-verbs actions, all actors on screen had the same gender, so

that toddlers could not use the gender of the pronouns to find which action was talked about. Each actor appeared in only one video.



**Figure 5:** Novel verbs and actions used in Experiment 2

All videos were accompanied by sound tracks recorded by a female native French speaker (the last author), who uttered all sentences in child-friendly speech. These sound tracks presented the novel verbs in each of the three experimental conditions (transitive, right-dislocated or intransitive). The sound tracks for the transitive condition presented the target verb in transitive structures such as [*Tu vois ça?*] [*Il<sub>i</sub> fome le garçon<sub>k</sub>*]. [*Regarde!*] [*Il<sub>i</sub> fome le garçon<sub>k</sub>*] (‘Do you see that? He<sub>i</sub> is foming the boy<sub>k</sub>. Look! He<sub>i</sub> is foming the boy<sub>k</sub>.’). In the right-dislocated condition the target verb was presented in right-dislocated structures such as [*Tu vois ça?*] [*Il<sub>i</sub> fome*], [*le garçon<sub>i</sub>*]. [*Regarde!*] [*Il<sub>i</sub> fome*], [*le garçon<sub>i</sub>*] (‘Do you see that? He<sub>i</sub> is foming, the boy<sub>i</sub>. Look! He<sub>i</sub>

is foming, the boy<sub>i</sub>.’). 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 sound track 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 the 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;  $M_{trans} = 444\text{ms}$  vs.  $M_{disloc} = 633\text{ms}$ ,  $t(15) = 12.91$ ,  $p < .001$ ), 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 to the same segments on the transitive sentences ( $M_{trans} = -45\text{Hz}$  vs.  $M_{disloc} = -151\text{Hz}$ ),  $t(15) = 5.27$ ,  $p < .001$ ). As in Experiment 1, there was no pause between the verb and the 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.

### 3.1.4. 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*, *nuver*) presented in one of the three experimental conditions: transitive, right-dislocated or intransitive. Each item included two 8s trials in which a pair of video events was presented together with the appropriate soundtrack for the condition.

In order 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-participants action). In this practice trial, all participants were asked to look towards the one who was *walking*. This practice item served to show children that in this experiment, 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 enough time to inspect each of the videos individually, on each side of the TV-screen (8s for each video). Five hundred milliseconds later, both videos disappeared, and a sentence containing the verb was presented during a 5-s blank-screen interval (e.g., ‘Hey, look! He will *fome*, the boy’). Next, the two videos appeared side-by-side on the screen for 8s, and at the same time participants heard the test sentence repeating the verb twice (e.g., ‘Do you see that? He is *foming*, the boy! Look! He is *foming*, the boy.’). Each test phase was repeated twice. Thus in total, for each item, participants heard 6 repetitions of the target word (4 repetitions while watching the two videos side-by-side; and two repetitions during the blank-screen interval with no videos on the screen). Figure 6 illustrates the time-course of presentation of each trial in Experiment 2.

The side of the screen the test video appeared on was counterbalanced within participants. For half of the items, a given participant saw the one-participant action on the left and the two-participants 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, or in right-dislocated sentences, or they heard them in intransitive sentences.

Note that while 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 4 pairs of videos. We added more trials in Experiment 2 in order to have more power in the study (and



because it was feasible, since the learning phase is much shorter in Exp. 2 than in Exp. 1 which had the dialogues before the test trials).



**Figure 6:** Time-course of trials presentation.

### 3.1.5. 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 is that looking times towards the two-participants 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-participants 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<sup>3</sup>. Both analyses were conducted on a total of 264 valid trial-items (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.

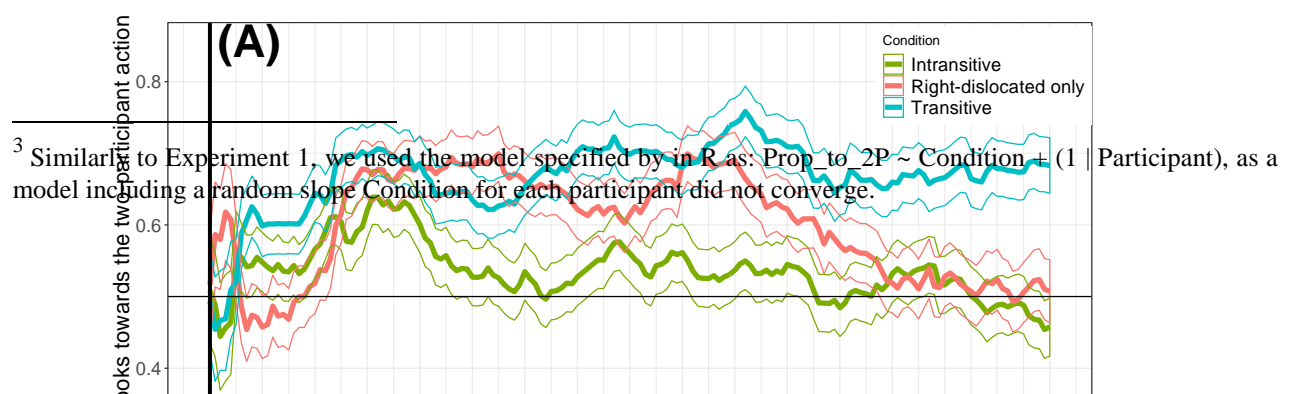
### 3.1.6. Hypotheses

Following previous studies (e.g., Yuan & Fisher, 2009; Yuan, Snedeker & Fisher, 2012), we expect children in the transitive condition to look reliably longer to 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, then children in the right-dislocated condition should look less towards the two-participant action than children in the transitive condition.

## 3.2. Results

### *Time course of eye movements to the two-participants action*

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



**Figure 7:** (A) Proportion of looks towards the Two-participants 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 in the intransitive condition (green curve). Non-parametric cluster-based permutations (Maris & Oostenveld, 2007) performed on the whole duration of the test trials (8s) 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 (about 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 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 trial).

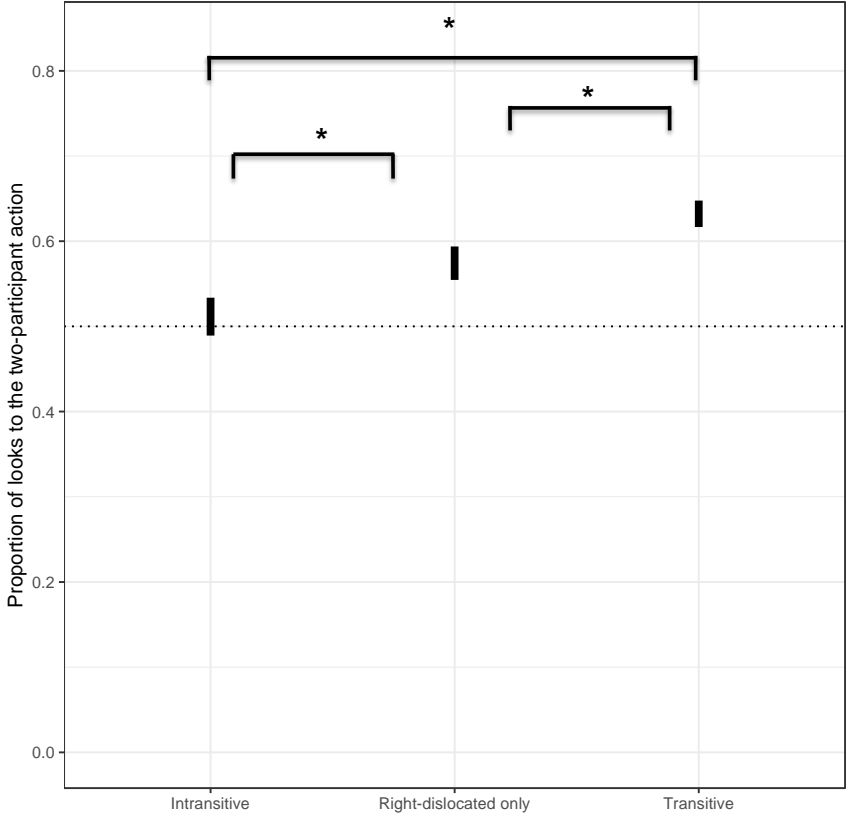
As can be seen in Figure 7, toddlers in all three conditions tended to look more towards the two-participant action right after the beginning of the trial. Toddlers in the transitive condition (blue curve) showed the largest preference towards the two-participant action, and looked more towards the two-participant 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, then remained around chance (0.5) 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 towards the two-participant action during the first repetition of the target word. However, from the second repetition, they increased their looks towards 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 towards the two-participant action was significantly different between toddlers in the transitive condition and toddlers in the right-dislocated condition (Fig 7-B), from 6400 ms until the end of the test-trial ( $p < 0.01$ ) (corresponding to the second repetition of the novel verbs). When we compared the proportion of looks towards the two-participants action between toddlers in the right-dislocated condition and toddlers in the intransitive condition, a significant time-window was found between 2100ms and 3500 ms;  $p < 0.05$ ; which coincides with the first repetition of the novel verbs (Fig 7-C). Finally, the cluster-based analysis found a significant time-window where the proportion of looks towards the two-participants action was significantly different between toddlers in the transitive condition and toddlers in the intransitive condition (Fig 7-D), from 4500 ms until the end of the trial ( $p < 0.001$ ).

*Proportions of overall looking times to the two-participants 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 (8s). As presented in Figure 8, looking times toward the two-participant action was modulated by Condition ( $\chi^2(3) = 6.98$  ;  $p < 0.001$ ).

We replicated previous studies using the same procedure (e.g., Yuan, Snedeker & Fisher, 2012): Children in the transitive condition looked reliably longer at the two-participants action than children in the intransitive condition ( $\beta = 0.43$ ;  $z = 4.33$ ;  $p < 0.001$ ). Critically, children in the right-dislocated condition looked reliably less at the two-participant action than children in the transitive condition ( $\beta = -0.23$ ;  $z = -2.26$ ;  $p < 0.05$ ), yet reliably more than children in the intransitive condition ( $\beta = 0.20$ ;  $z = 4.03$ ;  $p < 0.05$ ).



**Figure 8.** Proportion of looks towards the two-participants action averaged across the whole trial, for participants in the intransitive condition (green), in the right-dislocated condition (red) and in the transitive condition (blue). Error bars represent the standard error of the mean. Dots represent individual data points.

Taken together, these results show that toddlers’ looking preferences towards 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 did 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 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.

**3.3. 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<sub>i</sub> fome*], [*le garçon<sub>i</sub>*] (meaning the boy is foming), while watching a one-participant action versus a two-participant action, looked reliably less to the two-participant action than toddlers who listened to a novel verb in transitive sentences such as [*Il<sub>i</sub> fome le garçon<sub>k</sub>*] (meaning someone is foming the boy). Thus, observing possible referential scenes provided cues to the novel verb's semantic content (introducing the possibility that a verb refers either to a single or a two-participant event) and might have helped children to correct parse right-dislocated sentences. In other words, it is possible that by giving toddlers a forced choice (either video A or video B, therefore 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. This situation therefore might have helped children to bring out less frequent / 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 noun phrases.

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, greater proportion of looks toward the two-participant event than children exposed to intransitive sentences (Figure 8). There are two possible interpretations for 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 don’t show any significant preference for any of the two videos on the screen (see e.g., “baseline/neutral/control” condition in Yuan & Fisher, 2009; Yuan, Fisher, & Snedeker, 2012). So confusion in this kind of experiment would have surfaced as no preference for any 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 participants 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 Figure 7-C, during the first repetition of the novel verb in the test phase, toddlers in the right-dislocated condition looked more towards the two-participant action than toddlers in the intransitive condition before showing a 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, potentially 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.

#### **4. 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<sub>i</sub> is VERBing, the boy<sub>i</sub>’, 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’s the parsing strategy that most often applies for sentences containing 2 NPs, where the first NP is interpreted as the agent of the action and the second one as the patient, 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, since 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, *in press*; Fine, Jaeger, Farmer, & Qian, 2013; Gibson et al., 2013; Yurovsky, Case, & Frank, 2016). For instance, in Yurovsky, Case, & Frank (2016), 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, while the other group of children who were expecting plausible semantic sentences preferred to alter the perceptual information to reach a more plausible content ‘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, Case, & Frank, 2016) would help children select the most likely interpretation for a sentence in situations of uncertainty.

Yet we note that there may be an alternative explanation to the difference between our results and previous studies with right-dislocated sentences, one that relates to task difficulty. It could be that children, while 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, therefore 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, 2011; Brusini et al., 2016; de Carvalho et al., 2019; Yuan & Fisher, 2009; Waxman & Markov, 1995; Naigles, 1990). Which meaning children assign to words will thus depend on their representation of the structure of the sentence, which will in turn 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 may not necessarily reflect the immaturity of children's parsing system, but rather be indicative of what cues children consider reliable in that context.

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The authors declare that they had no conflicts of interest.

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### **Author Contributions**

**Alex de 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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