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"Really, he *dased* the doll to the girl?" Two-year-olds can exploit grammatical and thematic content to learn novel verb meanings

Giulio Massari [a,b,c,*], Vincenzo Moscati [c], Anne-Caroline Fiévet [d], Alex de Carvalho [a]

[a] *Laboratoire de Psychologie du Développement et de l'Éducation de l'Enfant – LaPsyDÉ, La Sorbonne, Université Paris Cité, CNRS, Paris, France*
[b] *Laboratoire Bases, Corpus, Langage – BCL, Université Côté d'Azur, CNRS, Nice, France*
[c] *Università degli Studi di Siena, Siena, Italy*
[d] *Laboratoire de Sciences Cognitives et Psycholinguistique – LSCP, École normale supérieure – PSL University, CNRS, Paris, France*

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ABSTRACT

Infants exploit the syntactic context verbs appear in to guide verb learning: a mechanism known as *syntactic bootstrapping*. However, it remains unclear whether infants' bootstrapping representations are achieved by matching the number of nouns in a sentence to the number of participants in an event, or by exploiting a more specific mapping between syntactic positions and thematic roles. To investigate this, we tested toddlers' ability to learn the meaning of a novel verb by relying on sentences' grammatical and thematic content, signaled by functional words connecting two noun phrases. French-learning 30-month-olds (n = 38) heard dialogues introducing a novel verb in either ditransitive sentences ('Le garçon va *daser* la poupée **à** la fille' – 'The boy will *dase* the doll **to** the girl') or conjoined-object transitive sentences ('Le garçon va *daser* la poupée **et** la fille' – 'The boy will *dase* the doll **and** the girl'). Toddlers were then asked to look for '*daser*' while watching two different events, containing three characters each: one depicted a transfer action, the other a causative action. Results showed that toddlers who heard the novel verb in ditransitive sentences looked more to the transfer event than those who heard conjoined-object transitive sentences. As both types of sentences contained three noun phrases, success in our task suggests that toddlers can go beyond the strategy of matching the number of noun phrases in a sentence to participants in an event. Therefore, the current study provides clear evidence that already at 30 months, grammatical and thematic content can guide verb learning.

1. Introduction

Previous research shows that infants exploit the syntactic context in which a novel verb occurs to infer its meaning (e.g., Yuan & Fisher, 2009). Yet, it remains debated to what extent toddlers can rely on cues other than the number of noun phrases (NPs) in a sentence to make such inferences. To investigate this, the present study tests whether 30-month-olds can use purely morphosyntactic cues, such as the alternation between a preposition and a conjunction, to infer different verb meanings from sentences containing the same number of NPs. Evidence of success would show that, at 30 months, toddlers can go beyond a simple NP-counting strategy and use morphosyntactic information to infer thematic relations and guide verb learning.

Toddlers can learn the meanings of novel verbs from sentence structure, using syntactic cues to constrain their interpretations: a process known as *syntactic bootstrapping* (e.g., Babineau et al., 2024; Fisher, Jin, & Scott, 2020; Gleitman, 1990; Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2005). For instance, while watching concurrent scenes illustrating possible event referents, 2-year-olds interpret a novel verb like '*gorping*' as referring to a causal two-participant event when it appears in a transitive frame ('The duck is *gorping* the bunny'), but not when it appears in an intransitive frame ('The duck is *gorping*': Naigles, 1990). However, little consensus is found concerning the nature of infants' initial bootstrapping representations.

* Corresponding author at: Campus Saint Jean d'Angely, SJA3 – MSHS/SE, Bâtiment de l'Horloge, 25 avenue François Mitterrand, 06300, Nice CEDEX 4, France.
E-mail address: giulio.massari97@gmail.com (G. Massari).

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The Structure-Mapping account (e.g., Fisher, 1996; Lidz, Gleitman, & Gleitman, 2003) proposes that infants' earliest verb meaning inferences arise from a strict alignment between syntactic and semantic representations. According to this perspective, before acquiring robust syntactic knowledge, learners may use the number of noun phrases in a sentence as a heuristic, assuming it matches the number of event participants (e.g., Fisher, 1996; Fisher et al., 2020; Gertner & Fisher, 2012; Lidz & Gleitman, 2004; Yuan, Fisher, & Snedeker, 2012). Thus, verbs occurring with two NPs ('The elephant is *chasing* the bunny') would be mapped to a two-participant, transitive interpretation, whereas verbs occurring with one NP ('The elephant is *running*') would be associated with a one-participant, intransitive interpretation (e.g., Nappa, Wessel, McEldoon, Gleitman, & Trueswell, 2009). Crucially, this view holds that NP-counting is only an early fallback strategy, used until children develop richer syntactic representations (e.g., Fisher et al., 2020; Lidz, Lukyanenko, & Sutton, 2021). This account is supported by many empirical studies showing that young children can successfully interpret novel verbs in accordance with the number of NPs they are combined with (e.g., Arunachalam & Dennis, 2019; Arunachalam & Waxman, 2010; Lee & Naigles, 2008; Lidz et al., 2003; Messenger, Yuan, & Fisher, 2015; Naigles, 1990; Scott & Fisher, 2012; Yuan & Fisher, 2009; see metanalysis in Cao & Lewis, 2022), but also by observations of erroneous inferences made by young toddlers when sentences and event referents do not respect this one-by-one matching (e.g., Dautriche et al., 2014; de Carvalho, Dautriche, Fiévet, & Christophe, 2021; Gertner & Fisher, 2012).

In fact, several findings indicate that toddlers sometimes default to NP-counting when structural representations are incomplete or underspecified. For instance, when parsing certain complex structures, 21-month-olds (Gertner & Fisher, 2012) and even 28-month-olds (Dautriche et al., 2014; de Carvalho et al., 2021) have been found to misinterpret intransitive sentences containing two noun phrases as transitive, linking them to causative events. In Gertner and Fisher (2012), when English 21-month-olds heard conjoined-subject sentences like 'The boy and the girl are *gorping*', they mistakenly interpreted '*gorping*' as a causative event performed by a boy on a girl. In Dautriche et al. (2014) and de Carvalho et al. (2021), when French 28-month-olds heard right-dislocated sentences featuring a novel verb ('Hei is *VERBing*, the boyi'), where a clear prosodic boundary after the verb indicated that the sentence was intransitive, such that the last NP 'the boy' was coreferential with the pronoun 'he', they incorrectly interpreted the sentence based on the number of NPs, assuming that someone else was '*VERBing*' the boy. This suggests that infants' initial bootstrapping is based on an incomplete representation of sentence structure, therefore susceptible to errors. However, in a follow-up study, de Carvalho et al. (2021) also showed that 27- to 30-month-olds flexibly shift between NP-counting and more fine-grained parsing, depending on available extralinguistic cues (e.g., when they saw videos illustrating possible meaning of the novel verb at the same time they heard the sentences) or syntactic cues (e.g., when they heard canonical 1-NP intransitive sentences alternated with right-dislocated sentences). Errors in these contexts, therefore, are generally not taken to imply that older toddlers rely *exclusively* on NP-counting, but rather that when syntactic cues are subtle or noncanonical, children in the third year of life can still fall back on simpler correspondences between NP number and participant structure.

An alternative proposal (i.e., Thematic Linking: Perkins, Knowlton, Williams & Lidz, 2025; Wellwood, He, Lidz, & Williams, 2015; see also Lidz, White, & Baier, 2017) challenges this hypothesis and assumes instead that toddlers are attuned to a broad range of linguistic cues beyond the number of nouns in a sentence to guide their parsing. According to this proposal, children use their developing knowledge of how grammatical relations (e.g., subject, object, indirect object) tend to map onto thematic roles (e.g., agent, patient, recipient) to guide verb learning. On this view, children parse sentences, identify syntactic relations, and then apply their prior expectations about how these relations typically correspond to event-level roles, even in absence of a concurrent scene from which to infer the verb's semantic content. These inferences about thematic structure, in turn, support inferences about the meanings of novel verbs.

Previous studies show that toddlers can engage in syntactic-thematic mapping when adequate referential support is provided. By around 24 months, children are sensitive to canonical word order and use syntactic positions to anticipate participants' roles in events (Gertner, Fisher, & Eisengart, 2006; Hirsh-Pasek & Golinkoff, 1996; Lidz et al., 2017). For example, Gertner et al. (2006) showed that 21- to 25-month-olds correctly interpreted a sentence like 'The duck is *gorping* the bunny' as more likely to describe a scene where a duck pushes a bunny, rather than another where the bunny pulls the duck. Similarly, Scott and Fisher (2009) found that, while viewing two simultaneously presented events, 28-month-olds inferred that an intransitive sentence with an inanimate subject (e.g., 'The pillow *dacked*') described an event involving a change to a patient (i.e., the pillow), whereas an intransitive sentence with an animate subject (e.g., 'He *dacked*') rather described an action performed by an agent. Together, these findings indicate that while observing events illustrating candidate referents for a novel verb's semantic content, toddlers can use linguistic cues such as word order and animacy, which correlate with thematic roles, to predict whether a sentence's subject is an agent or a patient.

A crucial question concerns whether morphosyntactic cues that support identification of grammatical relations and inferences about thematic structure can interact with, and possibly override, the counting strategy advocated by the Structure-Mapping hypothesis. In a recent study, Perkins et al. (2025) presented 20-month-olds with sentences containing fewer arguments than the participants represented in the corresponding scene. Infants watched a video of a girl taking a truck from a boy and heard either transitive sentences like 'She *pimmed* the truck' or intransitive sentences like 'She *pimmed*'. At test, infants viewed two side-by-side videos: one showing a girl taking the truck from the boy (3-participant event), and the other the girl moving the truck with no boy present (2-participant event). When asked 'Where is she *pimming* the truck?', infants in the transitive condition preferred to look at the 3-participant 'taking' event over the 2-participant 'grabbing' event, suggesting that they did not register a mismatch between the 2-argument clause and the 3-participant event. This behavior challenges the Structure-Mapping hypothesis, suggesting that infants do not rely solely on the number of syntactic arguments to map verbs to event structures.

While Perkins et al. (2025)'s results are compelling, they still leave some points open. These results suggest that infants can build thematic relations (e.g., agent, patient) out of grammatical content based on syntactic positions (e.g., subject, direct object). However, the use of a simple familiarization-test design coupled with (i) control sentences that differed in the number of NPs encoded, and (ii) concurrent visual scenes, makes it difficult to isolate which cue, or combination of cues, drove children's final interpretations. Simple cues like NP number, word order or animacy can be very useful to gain initial access to thematic content

(e.g., Gertner et al., 2006; Scott & Fisher, 2009), but they are also susceptible to errors (e.g., Gertner & Fisher, 2012). Visual information also provides cues to the verb's semantic content that can impact children's interpretations and avoid NP-counting mistakes (e.g., de Carvalho et al., 2021; Naigles, 1990). Therefore, it is yet to be seen whether toddlers can rely solely on morphosyntactic information to map argument phrases onto distinct thematic roles when no difference in NP number, word order, animacy, or visual referents is available.

Most evidence for the Structure-Mapping account, and most cases of NP-counting errors, come from dialogue-based studies (Arunachalam & Dennis, 2019; Arunachalam, Syrett, & Chen, 2016; Arunachalam & Waxman, 2010; Dautriche et al., 2014; de Carvalho et al., 2021; Messenger et al., 2015; Scott & Fisher, 2012; Yuan et al., 2012), in which children heard novel verbs without concurrent visual referents, and were shown to make syntactically guided inferences about verb meanings under purely linguistic input. By contrast, studies supporting the Thematic Linking hypothesis, i.e., showing that infants can move beyond NP-counting, have mostly provided simultaneous visual scenes illustrating possible meanings (Lidz et al., 2017; Perkins et al., 2025; but see also Perkins, Mateu and Hyams, 2025). This raises the question of whether observing events is necessary for accessing thematic structure. While these findings show that toddlers can form hypotheses about argument structure from NP number alone, they do not clarify whether they can extract finer-grained morphosyntactic distinctions to infer thematic structure without concurrent visual support. Indeed, de Carvalho et al. (2021) found that French 28-month-olds avoided NP-counting errors only when viewing potential event meanings; in a dialogue-only paradigm, they failed to distinguish structures containing the same number of NPs but with distinct thematic roles. Together, these results leave open whether toddlers can rely solely on morphosyntax to identify grammatical relations and infer different underlying thematic structures.

The functional lexicon plays a fundamental role in toddlers' word learning. Toddlers use function words such as determiners, pronouns, prepositions, and verbal affixes to infer the syntactic category of a novel word and its likely referent (de Carvalho, Babineau, Trueswell, Waxman, & Christophe, 2019; de Carvalho, He, Lidz, & Christophe, 2019; Fisher, Klingler, & Song, 2006; He & Lidz, 2017; St. Pierre & Johnson, 2021; Waxman, Lidz, Braun, & Lavin, 2009). They are also sensitive to functional elements that distinguish syntactic positions and cue thematic role assignment with novel nouns. For example, Lidz et al. (2017) and White and Lidz (2022) showed that 16- to 19-month-olds reliably mapped a novel noun to the appropriate event participant when hearing contrasts such as 'push the *tiv*' vs. 'push with the *tiv*' and observing concurrent visual scenes. Yet, it remains unknown whether these morphosyntactic cues can similarly support *verb* learning by guiding access to the verb's underlying thematic structure, especially when no visual referent is available during sentence processing.

The present study aims to investigate whether toddlers can rely on morphosyntactic cues – specifically, function words such as prepositions and conjunctions – to infer the thematic structure of sentences containing a novel verb. Although the debate between Structure-Mapping and Thematic Linking provides an important theoretical backdrop, the goal of the present study is not to adjudicate between these accounts in a global sense. Instead, our focus is to investigate whether toddlers can rely *solely* on morphosyntactic cues to identify distinct thematic structures for novel verbs when no differences in NP number, word order, or visual referents are available. While previous studies compellingly showed that toddlers can integrate syntactic-thematic information in contexts that include informative visual referents or multiple co-occurring cues (e.g., Lidz et al., 2017; Perkins et al., 2025; White & Lidz, 2022), they left open whether children can extract combinatorial syntactic information from language alone, as often the case in naturalistic learning (Yuan & Fisher, 2009).

To investigate this question, we tested infants' sensitivity to the contrast between ditransitive sentences and transitive sentences with a conjoined object.[1] Consider the following minimal pair in French, integrating the novel verb '*daser*':

(1) Le garçon va *daser* la poupée **à** la fille (The boy will *dase* the doll **to** the girl)
(2) Le garçon va *daser* la poupée **et** la fille (The boy will *dase* the doll **and** the girl)

Despite their similarity, these sentences realize different syntactic structures: in (1), the ditransitive construction encoded via the dative preposition 'à' ('to') signals a transfer event, with distinct Agent (i.e., the boy), Theme (i.e., the doll), and Recipient (i.e., the girl) roles; in (2), the transitive construction with the conjunction 'et' ('and') rather suggests a causal event where the third NP coordinates with the second, sharing its Patient role. This distinction between the ditransitive and transitive structure relies exclusively on the functional marker preceding the final noun phrase (i.e., 'à' vs. 'et'), rather than on the number or order of the noun phrases that each sentence encodes. Therefore, this contrast provides a stringent test of whether toddlers' interpretations reflect grammatical and thematic knowledge beyond simple NP-counting heuristics.

2. Method

We tested the contrast in (1)–(2) through the dialogue preferential looking paradigm (Yuan & Fisher, 2009) via eye-tracking. We presented

[1] Ditransitive structures and prepositional datives are well-studied in syntactic theory (e.g., Barss & Lasnik, 1986; Larson, 1988, 1990; Oehrle, 1976), and available evidence suggests that toddlers might be able to grasp the distinction between such contexts and transitive ones. Both ditransitive and transitive verbs, along with function words like prepositions and conjunctions, are present in toddlers' own speech from around 1.5 years of age (e.g., Chen et al., 2020; Snyder & Stromswold, 1997; Horvath, Rescorla and Arunachalam, 2019). Moreover, children from 3.5 years of age have been shown to understand ditransitive syntax and to be sensitive to different ditransitive constructions (e.g., Anderssen, Rodina, Mykhaylyk, & Fikkert, 2014; Thothathiri & Snedeker, 2008; Viau & Lidz, 2011). However, prior studies on verb learning in ditransitive frames offer limited comparability due to cross-linguistic and age-related differences. In English, ditransitives involve a structural alternation (e.g., double objects vs. prepositional datives: Larson, 1988), which may complicate parsing compared to French, where the structure is more transparent (Roberge & Troberg, 2007). Consistent with this, many studies on verb learning in ditransitive frames with English-speaking children between the ages of 3 and 5 yielded mixed results (Arunachalam, 2017; Conwell, 2019; Fisher, 1996; Rowland et al., 2014; Rowland & Noble, 2011). While Fisher (1996) showed that 3- to 5-year-olds can use both transitive (e.g., 'She is *blicking* the basket') and ditransitive structures (e.g., 'She is *blicking* the basket to/from her') to infer verb meanings while viewing simultaneous events, no previous verb learning study has directly contrasted ditransitive and transitive structures when these contain the same number of NPs and there is no concurrent referential scene providing clues to the verb's semantic content. Similarly, while conjoined subjects in verb learning have been studied more extensively (e.g., Arunachalam et al., 2016; Gertner & Fisher, 2012), conjoined objects in transitive frames remain largely unexplored.

French-learning 30-month-olds[2] with dialogues introducing a novel verb in either ditransitive sentences containing three noun phrases (1), or conjoined-object transitive sentences, also containing three noun phrases (2), in absence of any referential information. Toddlers were later asked to look for '*daser*' while watching two different events, containing three characters each: one depicted a transfer action involving three characters; the other depicted a causal action involving two characters, while a third character sat idly on the scene (Yuan et al., 2012). We hypothesized that if toddlers can use morphosyntactic cues to infer thematic content, they should interpret the novel verb used in ditransitive contexts as referring to a transfer event, whereas the same verb in transitive contexts as referring to a causative event. Therefore, at test, toddlers in the ditransitive condition should look more at the transfer event than those in the conjoined-object transitive condition. However, if toddlers rely solely on the number of noun phrases in a sentence, both groups should perform similarly, since both heard sentences containing three noun phrases.

Method, materials, and analysis were preregistered on the Open Science Framework before conducting the study, and are freely available at the following link: https://osf.io/tn5d2/?view_only=b981db78dec2415d96477b3a50465ef9.

2.1. Participants

Thirty-eight native French-learning toddlers, all recruited from the greater Paris area, participated in the study (age: M = 30.4 months, SD = 0.8, range 29.1–31.9; 23 girls). Eighteen children were assigned to the ditransitive condition and 20 to the transitive condition.[3] Five additional participants were excluded from analysis because of failure to complete the task, fussiness, technical problem, or excessive eye data loss. Participants' productive vocabulary was assessed through the French version of the Words and Sentence MacArthur-Bates Communicative Development Inventory for 16- to 30-month-olds (Kern & Gayraud, 2010; Kern, Langue, Zesiger, & Bovet, 2010). Mean total words produced were 512.45 (SD = 120.23, range 170–752); mean total verbs produced were 76.36 (SD = 23.91, range 8–100). This research was conducted in accordance with the recommendations of our local ethics committee (CER-ParisCité).

2.2. Apparatus

Participants were tested individually in a sound-attenuated booth in our Babylab. They sat on their parents' lap facing a 17-in. LCD screen positioned about 70 cm away. Participants' eye movements were recorded by an eye-tracker (Eyelink-1000) placed below the screen, operating in remote mode with a sample collected every 2 ms. During the task, caregivers wore headphones playing masking sounds such that they would not listen to the same stimuli as the child. The experimenter remained outside the booth throughout the experiment.

2.3. Materials and procedure

Following Yuan and Fisher (2009), the procedure was composed of three phases: practice, dialogue, and test. The practice phase familiarized toddlers with the task via four trials involving familiar verbs. Stimuli consisted of videos of puppets performing actions, accompanied by sound tracks recorded by a female native speaker of French. One pair of trials asked children to identify a familiar ditransitive verb ('donner' – 'to give' or 'lancer' – 'to throw'), whereas the other a familiar transitive verb ('ramasser' – 'to pick up' or 'pousser' – 'to push'), while looking at synchronized pairs of videos: one depicted a ditransitive meaning (giving or throwing) and the other a transitive meaning (picking up or pushing). Each verb item was used in two subsequent trials, and each participant heard two items in this phase (one transitive verb, one ditransitive verb), making up to four practice trials per participant. The order of items was counterbalanced across participants, such that half heard a familiar ditransitive verb first and a familiar transitive verb second, and the other half the reverse. The side of presentation for target videos (left vs. right) and the practice verbs heard ('donner', 'pousser' vs. 'lancer', 'ramasser') were also counterbalanced across participants.

The dialogue phase started three seconds after the end of the last practice trial. Participants watched videos of eight sentences-long dialogues featuring two female native speakers of French having a conversation, and introducing a novel verb (i.e., '*daser*') in one of the two experimental conditions (Fig. 1).[4]

Three seconds after the dialogue ended, the test phase began (Fig. 2). The two test trials showed videos of novel actions involving three characters: one depicted a novel transfer event, while the other a novel causative event with a bystander (Yuan et al., 2012). Each video was first shown alone for 5 s with a brief prompt (e.g., 'Hey look here!'). Then, during a 5 s blank screen with a fixation point, participants heard the novel verb in a neutral frame (e.g., 'Someone will *dase*!'). The videos then reappeared side-by-side for 8 s while the verb was repeated twice ('Do you see who is *dasing*? Look at the one who is *dasing*!'). Auditory stimuli at test were identical for all participants, the presentation side of the target video was counterbalanced, and eye-gaze was recorded throughout the experiment.

2.4. Measurement and statistical analysis

Test trials providing less than 75% of exploitable eye data were excluded from analysis. On average, each participant had 1.74 valid trials (SD = 0.45) and contributed with 96% of exploitable data per trial (SD = 0.06). Given our predictions and provided that looking times

[2] We chose to test 30-month-olds for two reasons. First, prior work has shown that children this age still sometimes rely on NP-counting heuristics, especially when syntactic cues are subtle or noncanonical, and immediate referential information is lacking (e.g., Dautriche et al., 2014; de Carvalho et al., 2021). Thus, examining whether toddlers can overcome NP-counting when morphosyntactic information is unambiguous offers an informative test of whether this heuristic persists beyond the earliest stages of verb learning when no visual referent is available. Second, much research on novel ditransitives has reported difficulties in comprehension well beyond the age of 3, leading earlier work to assume that children could not reliably parse ditransitive structures before 4 years of age (e.g., Conwell, 2019; Rowland et al., 2014: see also Footnote 1). Given these challenges, it was not a given that younger toddlers would be able to discriminate the particular morphosyntactic contrast tested here. For these reasons, 30 months represents the earliest age at which success was expected to be plausible.

[3] To estimate the number of participants needed, we conducted a power analysis based on the effects observed in previous verb learning experiments using the same paradigm (Dautriche et al., 2014; Yuan et al., 2012).

[4] In these dialogues, the actresses were instructed to produce the sentences naturally, as if they were speaking in front of a very young child, without any specific prosodic guidance. Because the lexical content, sentence structure, and number of noun phrases were closely matched across conditions, we did not implement any artificial manipulation of the audio files or attempt to control prosodic features (e.g., duration, intonation) beyond ensuring clear, fluent productions. Our design focused on manipulating only the presence of the critical function word (i.e., 'à' vs. 'et') in each type of sentence. This does not rule out, per se, the possibility that some prosodic differences covaried with the morphosyntactic contrast at issue here, providing additional cues to parse the target sentences.

toward the transfer and causative videos were complementary (away looking times did not reliably differ between conditions), the dependent variable for analysis was the proportion of looking times to the transfer action, computed for each time bin of 20 ms.

Following our preregistration, we ran two analyses.[5] First, we examined the time course of eye movements to identify any time window in which children looked reliably more to the transfer event in one condition than in the other, using a cluster-based permutation analysis across the full test trial period (e.g., Dautriche, Swingley, & Christophe, 2015; de Carvalho et al., 2021; Ferguson, Graf, & Waxman, 2018; Hahn, Snedeker, & Rabagliati, 2015).[6] Second, we compared overall looking proportions to the transfer event between conditions, as in prior verb learning studies using the same paradigm. We modeled the average proportion of looks in a mixed logit model with Condition (ditransitive, transitive) as fixed effect and Participant as random effect. The model used trial-level averages (one to two data points per child) and was fitted with a beta distribution via glmmTMB in R.

3. Results

Fig. 3 and Fig. 4 illustrate, respectively, the time course of eye movements toward the transfer event across conditions, and its overall proportion averaged over the entire duration of trials.

While a trend in the expected direction appeared when examining group means in Fig. 4, i.e., toddlers in the ditransitive condition looked descriptively more to the transfer event (M=0.63) than toddlers in the transitive condition (M=0.56), a mixed logit model did not reveal a reliable effect of Condition ($\beta = -0.19$, SE = 0.24, z = −0.82, $p = .41$). In contrast, the cluster-based analysis conducted on the time course of eye movements in Fig. 3 identified a significant difference between conditions during a specific time window, from 740 until 2361 milliseconds after trial onset ($p = .032$).

The cluster-based analysis revealed that toddlers in the ditransitive condition looked reliably more to the transfer event than toddlers in the conjoined-object transitive condition at a specific time window during test trials, lasting 1.6 s. This difference is concealed if average looking times are considered across the entire trial duration.[7] This pattern of results aligns with previous verb learning studies using similar paradigms, which often report early, short-lived effects of comparable duration that diminish over the course of the trial (e.g., Arunachalam, 2013; Arunachalam, Escovar, Hansen, & Waxman, 2013; de Carvalho et al., 2021). Importantly, our findings are consistent with research on time-sensitive language processing tasks, such as noun recognition, where effects typically emerge in discrete time windows rather than persisting throughout the trial (e.g., Bion, Borovsky, & Fernald, 2013; Dautriche et al., 2015; Swingley & Aslin, 2000).

Critically, most prior studies employing similar verb learning paradigms have focused on average looking times across entire trials, rather than examining the time course of gaze behavior (e.g., Dautriche et al., 2014; Yuan et al., 2012; Yuan & Fisher, 2009). This leaves open the question of whether the effects observed in such paradigms are inherently time-sensitive, peaking in specific windows, or whether they persist stably over time. Our findings suggest that such effects are quite transient, aligning with the notion that toddlers' interpretive strategies during verb learning may be concentrated in particular moments of heightened attention, reflecting the rapid and dynamic nature of language processing during early development.

4. Discussion

The present study investigated whether French 30-month-olds can rely *solely* on morphosyntactic cues (prepositions vs conjunctions) to go beyond the strategy of matching the number of nouns in a sentence to the number of participants in an event, and exploit a more specific mapping between syntactic positions and thematic roles to learn novel verb meanings. Our results provide clear evidence that even in absence of simultaneous referential information, toddlers distinguish between ditransitive and conjoined-object transitive sentences and infer different thematic contents from phrase-structure representations built from morphosyntactic cues. Crucially, as both types of sentences contained three NPs as potential arguments, the ability to map distinct meanings to the novel verb demonstrates that toddlers rely on more than just NP number when bootstrapping verb meanings. These findings provide novel and compelling evidence that toddlers' syntactic bootstrapping mechanisms are not limited to a heuristic of counting noun phrases to infer the number of participant slots in an event. Moreover, our findings extend recent studies in English (e.g. Perkins, Knowlton, Williams & Lidz, 2025; Perkins, Mateu & Hyams, 2025) by showing that French toddlers can extract combinatorial syntactic-thematic information from dialogue alone, and subsequently use it to guide attention to candidate events, providing converging evidence that children deploy rich syntactic-thematic knowledge to learn novel verbs when informative morphosyntactic cues are available.

By demonstrating that toddlers exploit grammatical markers, such as the function words ‘à’ and ‘et’, to learn novel verb meanings, our findings support a refined syntactic bootstrapping framework and contribute to the ongoing debate about the nature of early bootstrapping

[5] Note that in preferential-looking paradigms such as ours, comparisons to a fixed 0.5 chance baseline are not interpretable, because the two videos often differ in their intrinsic visual salience, and young children frequently show stable baseline preferences unrelated to the linguistic manipulation. For this reason, and following prior works using the same paradigm (e.g., de Carvalho et al., 2021), we preregistered only between-condition comparisons - specifically, time-course cluster analyses and overall-proportion analyses - which isolate the effect of the syntactic manipulation from any default visual preference.

[6] This analysis involved two steps: (a) the identification of time windows that have a potential effect of condition 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 proportions of looks to the transfer event between conditions was calculated, and adjacent time points with a t value greater than a predefined threshold ($t > 1.5$ on arcsin-transformed data) were grouped into a cluster. The size of the cluster was defined as the sum of the t values of each time point within the cluster. Then, a thousand simulations with conditions randomly shuffled were computed, and the size of the biggest resulting cluster was identified for each of them with the same procedure as for real data. A cluster of adjacent time points from real data was assessed to reveal a significant effect of condition if its size was greater than the size of the largest cluster found in 95% of the simulations, ensuring a p value of 0.05. For a formal presentation of the analysis, see Maris and Oostenveld (2007).

[7] Although looking patterns converged during the second test sentence, this does not undermine our interpretation. The causative event involved a repetitive action, whereas the transfer event unfolded more slowly toward a salient goal, likely drawing children's attention over time regardless of linguistic condition. Moreover, it is important to note that all children heard a full, neutral instance of the novel verb (‘Look, someone will *dase*!’) immediately before the test videos reappeared (during the preview audio phase) and had already inspected each event individually (during the inspection period). This design explains why differences between conditions appeared prior to the onset of ‘*daser*’ within the test trial. Thus, early differences likely reflect expectations formed prior to the test sentence, rather than any real-time difficulty with the processing of conjunctions or prepositions. The early divergence therefore indicates that toddlers' interpretations were guided by the morphosyntactic cues provided in the dialogue phase.

Ditransitive condition	
A) Hey, tu sais quoi ? Le garçon va *daser* la poupée **à la** fille !	A) Hey, you know what? The boy will *dase* the doll **to the** girl!
B) Ah bon, il va *daser* la poupée **à la** fille ?	B) Really, he will *dase* the doll **to the** girl?
A) Oui, et en plus, le papa a *dasé* le bébé **à la** maman.	A) Yes, and daddy *dased* the baby **to** mummy.
B) C'est vrai, il a *dasé* le bébé **à la** maman !	B) That's right, he *dased* the baby **to** mummy!
Ahahahahahahah	Hahahahahaha
…	…
A) Tu sais quoi ? Marie a *dasé* le doudou **au** bébé !	A) You know what? Mary *dased* the binky **to the** baby!
B) Quoi, vraiment elle a *dasé* le doudou **au** bébé ?	B) Really, she *dased* the binky **to the** baby?
A) Oui, et en plus, Jean va *daser* le chat **au** garçon.	A) Yes, and John will *dase* the cat **to the** boy.
B) Waouh, il va *daser* le chat **au** garçon !	B) Wow, he will *dase* the cat **to the** boy!
Ahahahahahahah	Hahahahahaha
Conjoined-object transitive condition	
A) Hey, tu sais quoi ? Le garçon va *daser* la poupée **et la** fille !	A) Hey, you know what ? The boy will *dase* the doll **and the** girl!
B) Ah bon, il va *daser* la poupée **et la** fille ?	B) Really, he will *dase* the doll **and the** girl ?
A) Oui, et en plus, le papa a *dasé* le bébé **et la** maman.	A) Yes, and daddy *dased* the baby **and** mummy.
B) C'est vrai, il a *dasé* le bébé **et la** maman !	B) That's right, he *dased* the baby **and** mummy !
Ahahahahahahah	Hahahahahaha
…	…
A) Tu sais quoi ? Marie a *dasé* le doudou **et le** bébé !	A) You know what? Mary *dased* the binky **and the** baby!
B) Quoi, vraiment elle a *dasé* le doudou **et le** bébé ?	B) Really, she *dased* the binky **and the** baby?
A) Oui, et en plus, Jean va *daser* le chat **et le** garçon.	A) Yes, and John will *dase* the cat **and the** boy.
B) Waouh, il va *daser* le chat **et le** garçon !	B) Wow, he will *dase* the cat **and the** boy!
Ahahahahahahah	Hahahahahaha

Fig. 1. Video snapshot and full transcription of the dialogues used in each condition. Original French is on the left, English translation is on the right. Dialogues were split into two 23 to 29 s videos containing four sentences each, separated by a 4 s blank screen. Ditransitive sentences (in red) and conjoined-object transitive sentences (in blue) contained the same words in the same order, except for the function word introducing the third noun phrase: 'à' ('to'), the Recipient role-assigning preposition, in the ditransitive condition vs. 'et' ('and'), the conjoining operator, in the conjoined-object transitive condition. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

mechanisms (e.g., Babineau et al., 2024; Fisher et al., 2020). Indeed, these findings challenge accounts positing that infants rely on coarse NP-counting heuristics (i.e., Structure-Mapping: Fisher, 1996; Lidz et al., 2003). In fact, they demonstrate that in an age range where erroneous inferences due to faulty parsing can still occur (Dautriche et al., 2014; de Carvalho et al., 2021), toddlers can integrate subtle grammatical markers to guide their parsing decisions, infer thematic roles from them, and learn verb meanings in turn. This supports theoretical models emphasizing the role of a rich, functional grammar that integrates morphosyntax and semantics from early on in development (Lidz et al., 2017; Perkins et al., 2025); Wellwood et al., 2015). It is important to emphasize that our results do not constitute, however, a wholesale rejection of Structure-Mapping. NP-counting may remain a default or fallback strategy for younger infants, and even for toddlers, when syntactic cues are subtle, structural analysis is underspecified or ambiguous, and visual information cueing verb meaning is unavailable. Rather, our findings show that, at 30 months, children *can* rely on morphosyntactic cues alone – specifically, function words marking grammatical relations – to infer thematic structure. By isolating the contribution of prepositions and conjunctions to guide parsing in the absence of informative referential scenes, NP number or word order cues, our study reveals that morphosyntactic cues can support thematic role assignment and verb learning.

Our results also extend prior research in important ways, underscoring the role of morphosyntactic information in guiding the growth of lexical semantics. Children's syntactic knowledge of function words has already been shown to be especially useful in inferring the meanings of novel words, with most previous research focusing on how children use determiners and pronominal/auxiliary morphology to infer whether a novel word refers to an entity or an action (e.g., de Carvalho, Babineau, et al., 2019; de Carvalho, He, et al., 2019; He & Lidz, 2017; Waxman et al., 2009). Relatedly, work by Lidz et al. (2017) and White and Lidz (2022) has shown that infants recruit functional markers such as prepositions to distinguish syntactic positions when learning novel nouns' meanings. The current study extends this research by showing that 30-month-olds can exploit their knowledge of different classes of function

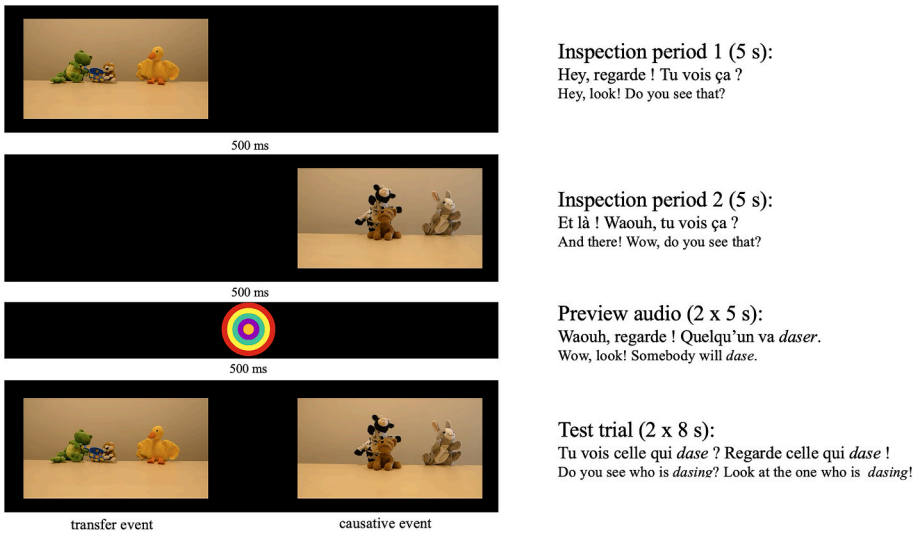

Fig. 2. Time course and content of the test phase. After watching the dialogue videos, participants were presented with two novel action videos that were first individually presented on different sides of the screen for 5 s (i.e., inspection period). Both videos featured three puppet characters. The transfer action pictured a frog bringing a lion cub to a duck using a colorful shovel. The causative action pictured a cow turning around the head of a doggie, while a rabbit sat idly on the side, not taking part in the action. After this, the screen cleared for 5 s before each of the two test trials, while participants heard one exemplar of the novel verb in a neutral frame (i.e., preview audio). At test, the two videos were presented simultaneously side-by-side on the screen for 8 s in each of the two test trials, and participants were asked to look at the one where a character was '*dasing*'.

words, e.g., prepositions and conjunctions, to identify thematic relations and constrain their interpretation of novel verbs.

While these findings are promising, some limitations warrant consideration. First, the present findings do not exclude the possibility that younger infants may rely more strongly on NP-counting as a default bootstrapping strategy. As noted by Fisher (1996) and Fisher et al. (2020), such heuristic may be used when syntactic representations are still developing, and subsequently abandoned as learners acquire finer-grained morphosyntactic knowledge. Future longitudinal or cross-sectional work, directly comparing younger and older toddlers in the context of a task like ours, will be needed to establish whether the ability demonstrated here at 30 months emerges earlier or reflects a developmental shift. Our decision not to include younger children was grounded in the robust evidence that French-learning toddlers, including 30-month-olds, still struggle with complex transitive constructions and occasionally default to NP-counting strategies (Dautriche et al., 2014; de

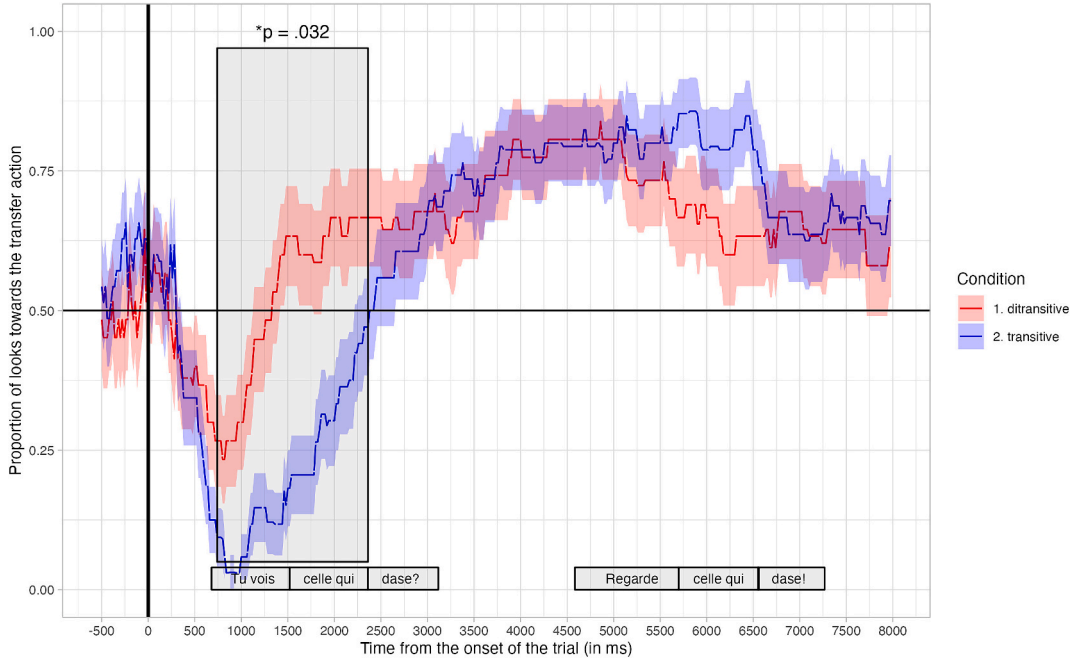

Fig. 3. Time course of the proportion of looks to the transfer event across conditions. Proportions of looks are visualized time-locked to the onset of test trials (vertical black line) for participants in the ditransitive (red curve) and conjoined-object transitive (blue curve) condition. A non-parametric cluster-based permutation analysis (Maris & Oostenveld, 2007) performed on the duration of test trials (8000 ms) revealed a significant difference between conditions in the time window highlighted by the black shaded area. Note that toddlers heard '*daser*' immediately before each test trial, and had already inspected both videos separately in the inspection period, which allows early condition differences to emerge before the verb onset in the analysis window. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

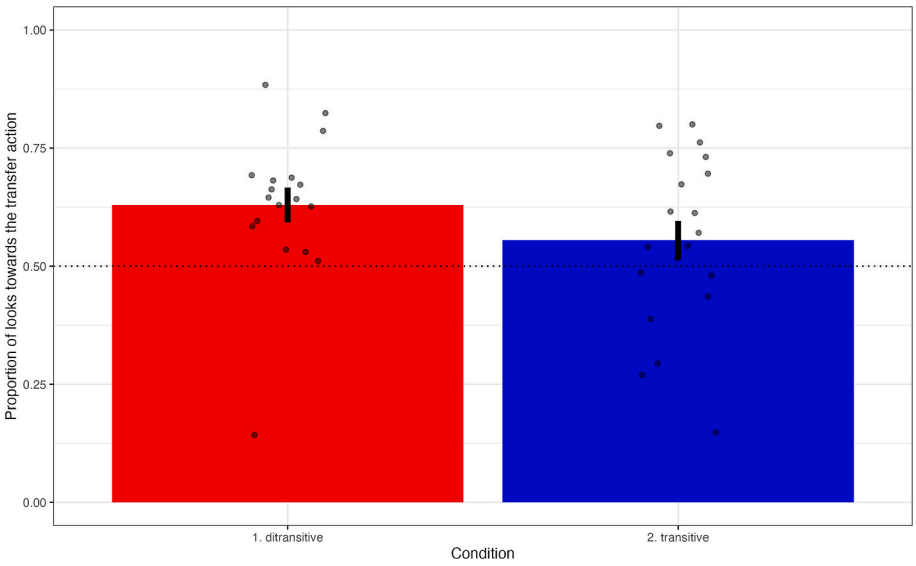

Fig. 4. Proportions of overall looking times toward the transfer event across conditions. Proportions of looks are visualized averaged at the trial level (8000 ms) for participants in the ditransitive (red bar) and conjoined-object transitive (blue bar) condition. Bar plots represent group means (ditransitive: M = 0.63, SD = 0.16; transitive: M = 0.56, SD = 0.18; Cohen's d = 0.41), while scatter points represent individual performances. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Carvalho et al., 2021). Thus, success at 30 months could not be assumed a priori. As our results now show that toddlers this age can use morphosyntactic cues to access distinct structures and infer thematic relations for novel verbs, future developmental work is well-positioned to test how and when this ability emerges.

Moreover, while our study shows the efficacy of a morphology-driven strategy to bootstrap verb learning, it would be desirable to evaluate the scope of this strategy beyond the specifics of French morphosyntax, as well as to embrace a comparative perspective considering other kinds of morphemes (e.g., case marking, agreement) that could trigger similar inferences. A further, related issue is the non-trivial interaction between morphological marking and word order. This is clearly visible in the double object/prepositional dative alternation of English, which allows the Recipient to be either introduced by a dative preposition (e.g., 'John gives a book *to Mary*'), or scrambled before the Theme (e.g., John gives *Mary* a book). This alternation may cause greater parsing difficulties than in French, where the structure is virtually unambiguous (e.g., Roberge & Troberg, 2007; see discussion in Rowland, Noble, & Chan, 2014). Future research could explore how toddlers acquire and exploit functional markers in these types of structures across typologically diverse languages.

Finally, one limitation of the present study concerns the potential contribution of prosodic cues. Although the two sentence types were closely matched in lexical content and number of noun phrases, we did not explicitly control or orthogonally manipulate prosody. It is therefore possible that subtle prosodic differences (e.g., phrasing or pause patterns) covaried with the morphosyntactic contrast ('à' vs. 'et'), leaving open the possibility that prosody could have played an ancillary role upon parsing the constituent structure of the target sentences. The general interplay between prosody and morphosyntax is well-known in linguistic theory (e.g., Nespor & Vogel, 1986), and it has been shown to influence toddlers' ability to learn new words (e.g., de Carvalho, He, et al., 2019). However, the specific impact of prosody on argument structure representations is still not fully understood, as are its interactions with morphology (e.g., de Carvalho, Kolberg, Trueswell, & Christophe, 2022; Kolberg, de Carvalho, & Christophe, 2025). In this respect, previous work suggests that toddlers are unable to infer the meaning of novel verbs in complex sentences from prosodic contrasts alone (e.g., Dautriche et al., 2014; de Carvalho et al., 2021). This casts doubts that success in our task could be reduced to prosody, but it leaves open questions about the synergy between suprasegmental phonology and the structural interpretation of the functional lexicon in guiding word learning. Future research designed to independently manipulate prosodic and morphosyntactic cues will be necessary to more precisely determine their respective contributions.

In conclusion, the current study reveals that toddlers' verb learning abilities critically depend on their sensitivity to morphosyntactic cues encoding thematic relations. The ability to incorporate grammatical cues signaling thematic relations in verb learning, even in absence of a concurrent scene from which to infer the verb's semantic content, suggests that toddlers' early syntactic representations are rich and highly structured – more so than the presence of occasional NP-counting errors might suggest – allowing learners to map sentence structure onto event structure in a fine-grained way. Therefore, these findings open new avenues for investigating the role of grammatical markers in early language acquisition, and contribute more globally to a deeper understanding of the mechanisms underlying syntactic bootstrapping.

CRediT authorship contribution statement

Giulio Massari: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Vincenzo Moscati:** Writing – review & editing, Writing – original draft, Conceptualization. **Anne-Caroline Fiévet:** Resources, Investigation, Data curation. **Alex de Carvalho:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT and Grammarly to enhance the readability and language of the manuscript. After using these tools, the authors thoroughly reviewed and edited the content as needed to ensure its accuracy and clarity, taking full responsibility for the content of the publication.

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Declaration of competing interest

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

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Data availability

The study reported in this paper, including the entire method, analysis, and criteria for exclusion of participants, was preregistered on the OSF (Open Science Framework) database before running the experiment. The formal preregistration, the stimuli used, collected data, and data analysis scripts are freely available to readers through the following link: https://osf.io/tn5d2/?view_only=b981db78dec2415d96477b3a50465ef9.

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