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Learning transitivity schemas: The role of the number of nominals and word order

The ability to understand and produce basic transitivity constructions serves as the foundation for human grammatical skills. While every clause or sentence in any given language follows a transitivity pattern, there is significant cross-linguistic variation in the specific formal elements used. Certain languages primarily rely on distributed cues, such as the number and ordering of noun phrases, while others prefer local devices like causative morphology or case markers. Extensive research has been conducted on the role played by the number and position of argument noun phrases in comprehending simple transitive sentences. This article offers a comprehensive review of the available evidence, covering typically-developing and monolingual populations, various languages, and different theoretical approaches. It also highlights gaps in the existing literature and provides suggestions for future investigations.

Key words: transitivity, distributed cues, word order, noun phrases, syntactic bootstrapping, language development

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Introduction

The ability to identify and use verb subcategorization frames is crucial for developing basic grammatical skills. Learners must recognize the linguistic devices and form-function mappings that contribute to understanding and producing these frames in their language (Slobin & Bever, 1982). These can be local cues that identify the roles of specific words within individual lexical items (e.g., case inflections on nouns, particles affixed to or immediately adjacent to verbs, specialized causative verb forms, or referent animacy) or distributed cues (also referred to as "global" or "topological") spanning multiple words or nonadjacent elements (e.g., Ammon & Slobin, 1979; Devescovi et al., 1998; Kail & Charvillat, 1988; Slobin, 1982). Distributed cues require generating, maintaining, and updating a representation of sentence structure in short-term memory, giving local cues a computational advantage (Ammon & Slobin; Kail & Charvillat, 1988). For instance, Kail and Charvillat (1986, 1988) found a correlation between processing cost of local and distributed cues, cue strength, and processing times in Spanish and French adults and children: local processing was preferred over distributed, resulting in shorter latencies (see also Kail, 1989; Devescovi et al., 1998). It has been argued that this processing advantage of local cues yields a developmental advantage for children learning languages with such cues, thus facilitating earlier productive development of transitive patterns (Ammon & Slobin, 1979; Slobin, 1982; Kail & Charvillat, 1988; Slobin & Bever, 1982). However, other factors might also influence children's use of local or distributed cues, including cue detectability and validity¹.

This article specifically targets two distributed cues: the number of nominals and word order (although word order could potentially be interpreted locally, see Footnote 1). These cues are universally accessible across languages (albeit with varying levels of reliability) and have been considerably studied, resulting in a substantial (and occasionally conflicting) evidence corpus in need of systematic organization. The number and position of argument noun phrases (NPs) have

1 Attention to cues is not solely determined by their local or distributed nature. Firstly, it is also influenced by cue detectability, which is affected by saliency, regularity, stress, final position, and juncture (Brandt et al., 2016; MacWhinney et al., 1985; Slobin, 1982). Secondly, attention to cues is also influenced by cue validity, determined by both cue availability and reliability (Bates & MacWhinney, 1989), with availability favored by younger children (e.g., Brandt et al., 2016; Devescovi et al., 1998; Dittmar et al., 2008a; MacWhinney et al., 1985; Sokolov, 1988). These additional factors may explain why some children learning languages with local cues follow global cues or do not exhibit a developmental advantage compared to those that lack them (e.g., see evidence by Wittek & Tomasello, 2005). Finally, it is possible that young children without fully developed short-term memory capacities use distributed cues, such as word order or agreement cues, in a "local" manner (e.g., Devescovi et al., 1998; Lindner, 2003). For example, a "first noun = agent" strategy may be applied locally by merely selecting the first noun encountered as the agent without considering the entire sentence. Thus, the use of a word order-based strategy as a truly distributed cue would depend on memory development (Devescovi et al., 1998; Kail & Charvillat, 1988).

been extensively researched regarding the comprehension of simple transitive sentences, mostly among typically-developing and monolingual populations. Thus, a comprehensive account of this research is valuable in the field. The availability of formal cues for forming and recognizing transitivity schemas, which affects children's expectations during sentence processing and the development of schema formation (e.g., Bates & MacWhinney, 1989), depends on the typology of the input language. Therefore, relevant findings on these factors are included throughout this article. In addition, evidence from various approaches, including the competition model (Bates & MacWhinney, 1989) and the structure mapping account (Fisher, 1996), which diverge on the role of language input, is considered.

This article is structured as follows: Section 1 focuses on the number of nominals, briefly introduced in 1.1, and delves into empirical and computational studies on the relation between the number of nominals and transitivity schema formation in 1.2. Section 1.3 presents two challenges posed by a learning strategy based on the number of NPs: an excess of NPs compared to verb participants and a shortage of NPs relative to verb participants. Section 2 addresses word order, succinctly introduced in 2.1. Section 2.2 discusses evidence of both early and later acquisition of word order learning and its exploitation for schema formation. Section 2.3 examines the interactions between word order and other cues, with a particular focus on local cues. Conclusions are provided in the final section. An Appendix is also provided, containing summarizing tables of the reviewed studies that present empirical evidence regarding the impact of the number of nouns and word order on the acquisition of transitivity constructions².

Number of Nominals

Counting Nouns as a Starting Point for Syntactic Bootstrapping

The structure-mapping account suggests that syntactic bootstrapping originates from a predisposition to align the number of NPs in a sentence with the number of participants in the conveyed event, establishing a one-to-one correspondence (Fisher, 1996, 2002; Fisher et al., 1994, 2020; Yuan et al., 2012). Children's familiarity with some nouns and verbs by the end of their first year of life or even earlier, as suggested by the "semantic seed hypothesis" (e.g., Babineau et al., 2021), enables them to use this heuristic. In contrast, Perkins, Knowlton et al. (2022) argued for a syntactic bootstrapping theory based on correspondences between syntactic positions and thematic relations. Their evidence contradicts the numerical matching hypothesis, as they showed that 20-month-olds accept a transitive clause to describe an event with three participants.

2 The Appendix has been uploaded to OSF and can be accessed using the following link: https://osf.io/w5hda/?view_only=bc5b6a4333604b25a5188915b7e35dc7

Empirical and Computational Evidence of the Structure Mapping Account in English

Experiments conducted on middle-class English-speaking children as young as 15 months old show their ability to use the number of NPs in a sentence to infer the meanings of novel verbs. They assign different interpretations to novel verbs based on the number of NPs in the sentence ("He's gorping" vs. "He's gorping him"), which indicates that children can establish connections between each noun and a core participant role, forming a coherent representation of an event.

Forced-choice pointing tasks with English-learning children at different ages, including 2;5 (Fisher, 2002), 3;6, and 5;3 years (Fisher, 1996), have shown that the number of NPs in a sentence influences their interpretation of novel caused motion verbs. When asked to identify the participant performing the action, children tended to choose the causal agent when the sentence contained two NPs and the patient when it contained only one NP. Following the same methodological paradigm, Ambridge et al. (2014) discovered that both children (aged 3;3 years) and adults used the number of NPs to interpret ungrammatical sentences with causative verbs (e.g., "Wendy is bouncing Bob" but see Naigles et al., 1993, 1992 regarding adult performance).

Evidence from preferential-looking tasks by Jin and Fisher (2014) and Yuan et al. (2012) revealed that infants as young as 1;3 years old can interpret the meaning of novel verbs based on the number of NPs in a sentence. Yuan et al. (2012) found that 1;7- and 1;9-year-olds exposed to transitive sentences watched the two-participant event longer compared to those exposed to intransitive sentences. Yuan and Fisher (2009) further showed that 2;5-year-old children found syntactic structure informative even without a referential context. Children were exposed to dialogues including novel verbs in either transitive or intransitive sentences during training (see also Arunachalam, Escovar, et al., 2013; Arunachalam & Waxman, 2010, among others).³ Similarly, Jin and Fisher (2014) used a monologue during training and found that 1;3-year-olds exposed to novel verbs in two-NP transitive sentences looked longer at the two-participant event during testing, while the opposite pattern was observed for those exposed to intransitive sentences. This result remained unchanged even when both scenes had an equal number of characters (using a bystander).

Act-out task studies with middle-class English-learning children aged 2;9, 3;7, 4;4 (Naigles et al., 1993), 5;9, 7;7, 9;7, 10;5 and 12;11 (Naigles et al., 1992) also revealed that they use the number of NPs in determining verb subcategorization. Children adjust their interpretation of familiar motion verbs to fit the syntactic environment in which the verb is presented ("frame compliance," by acting out "go" as "cause to go" or "bring" upon hearing "Noah goes the ark"). However, as they grow older, they shift towards favoring the typical meaning of the verb by

3 In some of these studies, the number and order of NPs in stimulus sentences overlap, making it difficult to determine whether children are matching NPs with participants or considering other cues (e.g., order).

adjusting the syntax (“verb compliance”).

Computational studies have also explored the assumptions underlying children's ability to interpret sentences based on the number of NPs, namely, that the learner can use distributional evidence available in naturalistic, child-directed speech to form grammatical categories such as “noun” and “verb” (Mintz, 2003; Weisleder & Waxman, 2010) and that a small number of words are initially categorized (Brusini et al., 2021). These studies have employed unsupervised hidden Markov models (HMM) trained on child-directed speech data to distinguish between arguments and predicates and assign semantic roles to nouns (Connor et al., 2010). Furthermore, incremental training of HMM models to mimic child learning has shown that a greater number of prior identified nouns is necessary to achieve the same level of accuracy in identifying verbs and nouns as non-incremental models (Christodouloupoulos et al., 2016). Other computational models have focused on filtering out problematic nonbasic clauses that may be parsed erroneously, such as object wh-questions (Perkins et al., 2017, Perkins, Feldman, et al., 2022).

Challenges to the Structure Mapping Account: Mismatches Between Noun Count and Event Participants

More Noun Phrases than Event Participants: Intransitive Sentences with Conjoined- or Dislocated-Subjects and Others. The structure-mapping account relies on the correspondence between NPs in a sentence and participants in the conveyed event, disregarding the grammatical roles of the NPs. Thus, it can lead to “immature” and error-prone sentence and event representations, especially when there is no such one-to-one correspondence. Despite this, evidence suggests that children may still employ this strategy, as indicated by certain errors they commit (e.g., Dautriche et al., 2014; Hirsh-Pasek et al., 1996).

Following the intermodal preferential looking design, Naigles (1990) found that 2;1-year-old English-learners looked longer at causal scenes when exposed to transitive sentences during training. In contrast, children exposed to conjoined-subject intransitive sentences (CSI) (e.g., “The duck and the bunny are gorpings”) looked longer at noncausal synchronous scenes, and these effects were significant, despite a baseline preference for noncausal synchronous scenes (Naigles, 1990; Naigles & Kako, 1993). Similar results were obtained in other preferential looking studies, including one with 1;9-year-olds using a dialog training phase (Arunachalam, Escovar, et al., 2013) and another with 3;6-year-olds, where children learned novel causal verbs by combining transitive and CSI frames across word-learning exposures (Chen et al., 2023). However, while transitivity significantly influenced looking times towards the causative scene, it still remains unclear if children's performance in the intransitive condition differs from random behavior.

In spite of these results, some studies have failed to replicate the effect of CSI syntax on children's preference for noncausal synchronous scenes. Children

struggle to discern the differences in meaning between CSI with two nouns and transitives (e.g., Bavin & Growcott, 2000; Hirsh-Pasek et al., 1996). English-speaking children aged 1;7, 2;0, and 2;4 (Hirsh-Pasek et al., 1996) behaved randomly when hearing a CSI like "See Big Bird and Cookie Monster bending."

Similarly, preferential-looking studies using CSI with the auxiliary verb "are" found no significant preference for either meaning (causal vs. noncausal) in children aged 2;0 (Pozzan et al., 2016), 2;2 (Bavin & Growcott, 2000), and 2;5 (Hirsh-Pasek et al., 1996). The same outcome was observed using the forced-choice pointing paradigm in children aged 2;3 (Arunachalam & Waxman, 2010) and 3;0 (Arunachalam et al., 2016), using a dialogue training phase, and 2;3 and 2;7 (Noble et al., 2011). However, children significantly matched the CSI with non-causal synchronous scenes at older ages: 3;4 (Noble et al., 2011) and 4;3 (Noble et al., 2011, 2016). Surprisingly, Hirsh-Pasek et al. (1996) also found this with their younger group, aged 2;0.

Gertner and Fisher (2012) and Noble et al. (2016) proposed that the observed outcome stemmed from a parsing error. In their studies, 1;9-year-olds failed to map the CSI correctly when the first noun matched the agent in the distracting causative scene, but not when it matched the patient (Gertner & Fisher, 2012). However, conflicting results were found with Mandarin learners (Jiang & Haryu, 2014). Noble et al. (2016) further noted that 3;4-year-olds were misled by the CSI only when both nouns were animate, but not when one was inanimate (matching either the agent or the patient of the distracting causative scene). Therefore, children can rule out the causative interpretation of CSI when word order (agent-patient) and animacy (animate-inanimate or inanimate-animate imbalances) do not align with the canonical transitive construction. This indicates that syntax alone is insufficient in this case.⁴

Adding formal cues can help children match CSI with noncausal scenes, by encouraging them to correct any initial parsing errors. For example, using "with" ("Look Big Bird turning with Cookie Monster") enabled girls aged 1;11 (Hirsh-Pasek et al., 1996), and children aged 2;2 (Bavin & Growcott, 2000), and 2;4 (Hirsh-Pasek et al., 1996) to associate the intransitive syntax with noncausal scenes. The use of "together" ("Sam and the girl biffed/are going to beef together") had a similar effect on 3;3-year-old English-speaking children, adult English speakers, and adult Mandarin speakers, although it did not have the same effect on 4;7-year-old Mandarin-speaking children (Arunachalam et al., 2016). The Mandarin equivalent of "each" also produced the same effect on both adults and 3;10-year-olds.

However, other researchers argue that children parse these sentences correctly, but intransitive syntax can be associated with both general causative scenes ("They are playing") and synchronous noncausal scenes (e.g., Arunachalam &

4 Stimuli presentation may provide additional cues. Pronominalization in training dialogues helped 1;9-year-olds associate two-noun CSI with non-causal scenes (cf. Noble et al., 2016).

Waxman, 2010; Pozzan et al., 2016). Certain features, such as having one animate and one inanimate NP, discourage children from assuming the former, reducing the likelihood of joint action. Pozzan et al. (2016) found that 3;0 and 4;0-year-old children prefer noncausal synchronous scenes when CSIs involve one animate and one inanimate character, but behave randomly when both characters are animate. This is not due to parsing errors, but rather to additional cues that discourage the general causative meaning associated with CSI. In fact, adult participants tend to make the same mistake regardless of noun animacy (Arunachalam et al., 2016; Pozzan et al., 2016), suggesting that a lack of syntactic knowledge is unlikely to be the cause of this outcome.

This finding has been supported in other languages as well. Using a preferential looking design, Koulaguina et al. (2019) found that French-learning children correctly interpreted CSIs at 2;0 and 2;6 (although with difficulty) but not at 1;6. Mandarin-learning children of various ages (2;6, 3;5, 4;4, and 5;5) failed to match CSIs to noncausal synchronous scenes in a pointing task (Jiang & Haryu, 2014), and Japanese-learning children aged 2;4 also struggled to do so in a preferential looking task (Matsuo et al., 2012).

Children's errors in interpreting verb subcategorization frames when there are noun-participant mismatches have been also documented in the case of right-dislocated intransitive sentences. In a preferential looking experiment with a dialogue training phase, Dautriche et al. (2014) found that French-learning 2;4-year-olds struggle to consistently apply this knowledge with novel verbs, which place high demands on their parsing system. This contrasts with evidence showing that French children are capable of producing dislocated constructions and mastering the prosodic rules governing dislocation from an early stage (De Cat, 2007). In fact, in the study, children comprehended right-dislocated sentences with familiar verbs (e.g. *Ili dort, le lapini* "It is sleeping, the bunny"; see also Vion, 1992 for transitives with right or left dislocation). In line with this, De Carvalho et al. (2021) suggested that, in uncertain situations, toddlers may rely on the parsing strategy usually used for sentences with two NPs, interpreting the first NP as the agent and the second NP as the patient.

There are other cases in which the number of NPs in a sentence exceeds the number of arguments in the event, such as light verb constructions (e.g., "give a kiss;" He & Wittenberg, 2020, for a review). Additional NPs or prepositional phrases can also be present as adjuncts in sentences. While there is evidence that children can recognize some of these cases (Leischner et al., 2016), they are not fully explained in the literature on the structure mapping account.

Fewer Noun Phrases than Event Participants: Omitted Nouns and Competing Cues. Another challenge for an NP-based heuristics is noun shortage. In some languages (e.g., Turkish, Japanese) argument NPs can be omitted when the context makes their referents clear (e.g., Narasimhan et al., 2005), which limits the reliability of the number of NPs cue. In addition, the syntactic simpli-

city and brevity of child-directed utterances, as compared to adult-directed ones (e.g., Martin et al., 2016), may also diminish the likelihood of using the matching mechanism described, especially if this simplicity stems from frequent argument omission (Audisio & Migdalek, 2020). However, input during natural mother-child interactions is proposed to support the acquisition of verb argument structures through variation sets and expansions (Kayama & Oshima-Takane, 2022). In addition, caregivers use more overt arguments when children start uttering words at 1;9, with variations among caregivers influencing children's outcomes (Kayama & Oshima-Takane, 2022).

Some studies have measured argument omission in child-directed speech in different languages. English shows 30% subject omission (Cameron-Faulkner et al., 2003), Mandarin exhibits 50% subject omission and 34% object omission (Zhu & Gavarró, 2019), Japanese shows 66% subject omission (Matsuo et al., 2012; Rispoli, 1989) and 20% (Rispoli, 1989) to 47% object omission (Matsuo et al., 2012), Korean exhibits 60% subject omission and 45% object omission (Kim, 2000), Spanish shows 62% subject omission with many declarative sentences lacking objects (Aguado-Orea et al., 2019), Tagalog exhibits 15% subject and object omission (Garcia & Kidd, 2022), and so on (Lee & Naigles, 2005; Narasimhan et al., 2005; Shin, 2021, etc.).

Differences in argument drop across languages can affect which contexts are supportive of verb learning (Arunachalam, Leddon et al., 2013; Imai et al., 2008). Using a pointing task, Arunachalam, Leddon, et al. (2013) found that, while 2-year-old Korean learners struggle with both overt and dropped arguments, English learners perform better with rich linguistic contexts containing two overt arguments. However, Shi et al. (2023) found that by age 4, both English and Korean learners can process sentences with overt subjects and learn novel verb meanings, regardless of argument drop in their language.

Furthermore, in languages with more reliable transitivity cues like case-marking affixes, children may use alternative methods to learn the basic transitivity structures, which may lead to a weaker or absent influence of the number of NPs compared to English. However, evidence of the noun-to-argument matching mechanism exists in children learning such languages: Kannada (Lidz et al., 2003; Trueswell et al., 2012), Mandarin (Lee & Naigles, 2008), Turkish (Göksun et al., 2008), Tagalog (Trueswell et al., 2012), and German (Leischner et al., 2016).

Following Naigles et al. (1993)'s act-out design, these studies presented 2;7, 3;4, 4;5 and 5;3-year-olds acquiring Turkish (Göksun et al., 2008), 3;6-year-olds acquiring Kannada (Lidz et al., 2003), and 3;6, 4;4, 7;5 and 9;5-year-olds acquiring German (Leischner et al., 2016) with grammatical and ungrammatical sentences containing familiar transitive and intransitive verbs of motion (e.g., "The sheep goes" and "*The sheep goes the horse"). The sentences contained one or two NPs and may or may not include morphological information: causative verb suffixes (Turkish and Kannada) or accusative case markers (Turkish and German). The results indicated that the number of NPs in the sentence affected children's cau-

sative or noncausative interpretation of verbs. Regardless of verb transitivity, the presence of a second NP led children to interpret the sentence as causative while its absence resulted in a noncausative interpretation.⁵

It is worth noting that causative and case affixes in Kannada and Turkish are better predictors of causative meaning than the number of NPs. German, another case-marked language, differs from Turkish in that case marking mostly occurs on determiners and some case forms are the same for certain genders. In addition, the object NPs cannot be omitted, and subject NPs are rarely omitted. The results with Turkish and German-speaking children showed that the presence of accusative case markers significantly influences sentence interpretation. Turkish learners interpret intransitive verbs as causative more often with one noun marked for the accusative case (Göksun et al., 2008). Similarly, German children and adults assign more causative interpretations to ungrammatical sentences when they are distinctly case marked (Leischner et al., 2016). In turn, the effect of case markers on Kannada-learning children is unclear as it was not specifically assessed (Lidz et al., 2003).

In contrast to Turkish, Kannada and German, Mandarin Chinese lacks other reliable cues for causativity beyond NPs, which are often omitted. Lee and Naigles (2008) found that 2;8- and 3;8-year-old Mandarin learners can extend causative and noncausative meanings to familiar verbs in transitive two-NP and intransitive one-NP sentences, respectively. However, Jiang and Haryu (2010) argued that exposure to English in Singapore, where English is an official language, may have influenced participants' understanding of the relationship between argument number and causativity. They also questioned whether the act-out task overestimated children's knowledge of causatives. Using a pointing task with novel verbs, Jiang and Haryu (2014) tested Chinese-speaking children aged 2;6, 3;5, 4;4, and 5;5 from China. The results showed that children more frequently selected causative events in transitive sentences compared to intransitive sentences. However, they performed at chance in the intransitive condition even at 4 or 5 years of age (see Section 1.3.1). The authors did not find a bias to interpret the first noun of conjoined-subject intransitives as the agent and the second as the patient. Instead, they attributed the slower development of Chinese children in understanding conjoined intransitives to the possibility of argument dropping in the language, which can cause confusion between intransitive sentences and transitive sentences with omitted objects.

Contrary to claims that children focus on consistent properties of their input language (e.g., Bates & MacWhinney, 1989), evidence of the structure mapping mechanism at a young age (1;3 years; Jin & Fisher, 2014) and that children follow

5 However, in Lidz et al. (2003), the effect of the second NP is confounded with the presence of the accusative case marker. In addition, these results should be compared with the preliminary findings from a selection task conducted by Reddy and Deen (2023), who seemingly found that the number of NPs was insufficient for Marathi-learning 4;6- and 5;7-year-olds to interpret 2-NP sentences with intransitive verbs as referring to causal events.

weak cues in Mandarin and disregard strong cues in Turkish and Kannada supports the claim of a universal and innate mechanism (also supported by evidence from deaf children: Feldman et al., 1978; Goldin-Meadow, 2005). However, language-specific variations were observed in the experiments. English learners are more influenced by the presence of a second NP with intransitive verbs, while Mandarin and Turkish learners are less affected (Göksun et al., 2008; Lee & Nigles, 2008). German learners also show a weaker influence of the number of NPs compared to English learners (Leischner et al., 2016).

According to Fisher et al. (2020), children learning these languages compensate for the unreliable number of NPs by semantically categorizing nouns to determine their likely argument roles, making probabilistic inferences about verb combinatorial behavior (see also Ural et al., 2009), and maintaining discourse continuity (e.g., Horowitz & Frank, 2015; Wittek & Tomasello, 2005). Jin (2015) found that English-speaking children's attention to transitive or intransitive dialogues is influenced by the presence of a coherent discourse context which helps children fill in missing arguments. In addition, Korean-speaking children's understanding of novel verbs is guided by the transitivity of training dialogues, even when they show argument omission.

Word Order

Word Order as Cue to Clause Transitivity

Cross-linguistic evidence suggests that children develop schemas based on canonical sentence forms, incorporating typical features such as word order and basic morphology (Slobin & Bever, 1982). Word order serves as a syntactic mechanism for encoding grammatical relations, but its reliability varies across languages (and construction types; Brandt et al., 2016). Accordingly, experiments with adults and children have shown cross-linguistic differences in reliance on word order (e.g., Bates et al., 1982). Given the redundancy between grammatical cues and word meanings, research with adults questions the usefulness of word order as a cue to the meanings associated with transitivity (Mahowald et al., 2022). However, redundancy between formal cues may aid learning in children (Tal & Arnon, 2022).

When do Children Learn Their Language's Word Order?

Based on the developmental stage at which children master this aspect of grammar, much of the literature on word order acquisition has argued in favor of either early or later acquisition of word order. The "early" or "later" element has often been considered as evidence for one of two opposing theories on grammar acquisition. One postulates early abstraction skills based on innate rules, requiring

minimal exposure to the linguistic environment and resulting in immediate and widespread productivity (e.g., Fisher et al., 1994; Gertner et al., 2006; Marcus et al., 1999; Zhu et al., 2022). The other posits gradual abstraction skills, involving longer exposure to language input and resulting in progressive and piecemeal application of word order patterns (e.g., Akhtar & Tomasello, 1997; Matthews et al., 2005; Olguin & Tomasello, 1993; Roberts, 1983). In the following section, evidence of early and late acquisition is grouped, and the interpretation of this evidence is discussed. However, a middle ground (see Shin, 2022) is represented, for instance, by those who have proposed early acquisition of abstract representations while acknowledging a role for the input: either as a boost to the productivity and systematic application of the early abstractions or as the basis for their creation, which might occur rapidly with a considerable amount of experience (e.g., Abbot-Smith et al., 2017; Dąbrowska & Tomasello, 2008; Smolik, 2015). Thus, this middle ground challenges the idea that "early" or "late" necessarily implies one or the other strong version of each theoretical option.

Evidence of Early Acquisition. Some studies suggest that children already possess implicit knowledge of word order in their native language when they begin combining words productively (e.g., Benavides-Varela & Gervain, 2017; Marcus et al., 1999). They rarely commit errors in production and, as observed in comprehension studies primarily conducted in English, they use word order in interpreting sentence schemas as transitive. Children's attention to word order may even lead them to focus on NP position alone, disregarding the verb, as seen in the causal interpretation of conjoined-subject intransitive sentences with the first NP as the agent (see Section 1.3.1; e.g., Gertner & Fisher, 2012; Noble et al., 2016).

Multiple studies have shown that children have a bias to interpret the first noun as the agent from early on (e.g., Abbot-Smith et al., 2017; Bever, 1970; Gertner et al., 2006; Lempert & Kinsbourne, 1978; Strohner & Nelson, 1974, for English; Sinclair & Bronckart, 1972, for French). However, the role of this strategy in children's comprehension has been mitigated by evidence from case-marking languages (e.g., Hakuta, 1982; Özge et al., 2019; Shin, 2021; Slobin & Bever, 1982), consideration of other strategies (e.g., the use of extralinguistic cues in act-out tasks, Bridges, 1980), and the influence of pragmatically appropriate contexts (Thomsen & Poulsen, 2015). Additionally, studies have explored the impact of input on this preference, as observed in Tagalog-learning children aged 5 and 7 who exhibit an agent-initial preference arguably influenced by input frequency factors (Garcia et al., 2018; see also Shin & Mun, 2022, for Korean).

English-learning children aged 1;9 and 2;1 appropriately use word order to interpret transitive sentences, as shown in preferential-looking experiments with novel verbs and caused-motion scenes with matching or reversed theta-roles (Gertner et al., 2006). This ability can even be observed as early as 1;5, provided that sentences contain familiar instead of novel verbs (e.g., "The horse is washing the bird" vs. "The bird is washing the horse;" Candan et al., 2012; Hirsh-Pasek &

Golinkoff, 1996). Moreover, 1;11-year-old English-learning children can map NP positions to roles in a scene, even when the participants' asymmetry is less apparent than in caused-motion events (Scott et al., 2018). Act-out tasks further revealed that English-learning children aged 2;6 (Bates et al., 1984; Chan et al., 2009) and 2;9 (Naigles et al., 1993) exhibited sensitivity to word order, with a tendency to make the preverbal NP the agent when hearing transitive sentences expressing causal actions with familiar transitive and intransitive verbs.

The ordering of NPs also helps English-speaking children aged 3;8 and 4;8 in interpreting the meaning of novel verbs related to overlapping events (Fisher et al., 1994). Additionally, children aged 3;6, 4;5, and 5;9 use speaker's eye gaze to determine the subject in scenes with uninformative sentences but rely on word order to infer verb meaning in the presence of informative transitive sentences (Nappa et al., 2009). Furthermore, computational modeling studies have shown that models incorporating information on NP number and order learn to interpret the first NP as the agent and the second as the patient (Connor et al., 2008).

Moreover, 2-year-old (and even younger) children learning languages other than English (e.g., French, Hindi-Urdu) have intuition about the canonical word order in their languages. In a study involving artificial grammar learning, 8-month-old children learning French, an SVO language with minimal presence of null arguments, showed early sensitivity to their language's word order, potentially based on the ordering of function and content words in their input (Bernard & Gervain, 2012; see also Gervain et al., 2008, for the same result with 8-month-olds acquiring Japanese and Italian). Additionally, using the weird word order (WWO) paradigm (Akhtar, 1999)⁶ in preferential looking tasks with eye-tracking, Franck et al. (2013) found that French-speaking 1;7-year-olds look longer at the causative matching scene (instead of reflexive) when presented with well-formed NVN sequences, but perform randomly with ill-formed NNV word orders. Another study following the WWO paradigm found that at 2;11 and 3;11, French learners correct sentences with noncanonical word orders and rarely use noncanonical constituent orders, even with novel verbs (Franck et al., 2011). In an act-out design, Kail and Charvillat (1986, 1988) revealed that French learners initially rely on word order to interpret transitive sentences (at 2;6, 3;6), but gradually shift their attention to animacy information (at 4;6), especially when confronted with noncanonical orders like NNV and VNN.

Using a combination of the WWO paradigm with novel verbs and the preferential looking paradigm, it has been found that 1;5-year-old Mandarin-learning children direct their gaze towards causal (rather than reflexive) scenes upon hearing well-formed NVN sentences, but exhibit random looking patterns for ungrammatical NNV sequences (Zhu et al., 2022). In addition, a forced-choice pointing study with novel verbs suggested that Mandarin learners as young as

6 Chang et al. (2009) objected that the use of WWO is mediated by children's representations of their interlocutors' linguistic knowledge.

2;4 years demonstrate understanding of both grammatical canonical (SVO) and grammatical non-canonical (SOV) word orders (Hsu, 2018; cf. Candan et al., 2012; Chan et al., 2009), aided by early abstract knowledge of word order and case markers. Mandarin, an SVO language like French, permits subject and object dropping if recoverable from discourse context. It allows alternative word orders (SOV, OSV, VOS), often indicated by morpho-syntactic markers like "ba" (for objects) or "bei" (for passive voice). In Polish, a flexibly ordered SVO language with case-marking, subject-verb agreement and argument dropping, early awareness of canonical word order is observed as well. Weist (1983)'s act-out study showed that 2;6- and 3;6-year-olds rely on word order to comprehend NVN sentences without clear inflectional cues, sometimes mistakenly interpreting OVS as SVO. However, when inflectional information is present, they use nominative and accusative suffixes to assign agent and patient roles.

SOV languages like Hindi-Urdu and Turkish, known for their flexible word order, argument omission, and case-marking, also show early acquisition of word order. Gavarró et al. (2015) used the WWO paradigm with novel verbs and the preferential looking paradigm to find that 1;7-year-old Hindi-Urdu learners gaze longer at causal (vs. reflexive) scenes upon hearing well-formed case-marked SOV sequences, but fail to assign consistent interpretations to deviant case-marked VSO sequences. Turkish learners show sensitivity to canonical SOV word order at 2;3 and 3;1, but not at 1;6 (later than in English, as shown by Candan et al., 2012). Candan et al. (2012) used a preferential looking design where children heard canonical SOV transitive sentences with familiar verbs but without case-marking (i.e., ungrammatical) and viewed simultaneous scenes with reversed roles.

Evidence of Later Mastery. Some studies suggest that children's grasp of English canonical word order may not fully develop until around the age of 3 or even 4. This has been interpreted as support for the idea that the acquisition of word order is a gradual process, involving generalization from examples, and that children may initially form "weak" or "partial" representations of abstract syntactic structures (e.g., Bridges, 1980, 1984; Tomasello & Abbot-Smith, 2002). In fact, it has been argued that positive results with younger children (e.g., 1;9-year-olds in Gertner et al., 2006) may be influenced by the impact of linguistic experience during training (Dittmar et al., 2008b) or the different demands of the preferential looking method, which may require weaker and/or partial representations compared to act-out tasks (Chan et al., 2010).

In act-out tasks, English-learning children at 2;0 and 2;1 could not use word order in sentences with novel action verbs (e.g., "Make Mickey Mouse gorp Ernie") to interpret the roles of toy participants (Chan et al., 2010; Olguin & Tomasello, 1993). They were equally likely to assign the post-verbal NP as either the agent or the patient. They show some understanding of word order at 2;9 but still perform better with familiar rather than novel verbs in act-out tasks (Chan et al., 2010). At around 3;6, they can use word order to interpret agents and patients

with novel verbs (Akhtar & Tomasello, 1997), and with both novel and familiar verbs in both act-out and preferential looking tasks (Chan et al., 2010). The well-known study by Slobin and Bever (1982) also showed that English-learning children can use a strategy based on the canonical NVN word order at around 3;6 to enact reversible transitive sentences. In addition, in the first study using the WWO paradigm (Akhtar, 1999), English-learning children exhibited clear understanding of the canonical SVO word order at 4;4, consistently rearranging sentences to match the grammatical SVO order. However, at 2;8 and 3;6, children were equally likely to use noncanonical word orders with unfamiliar verbs as they were to correct them to SVO.

The item-based nature of children's word order acquisition was further supported by evidence that children's acquisition of word order is initially limited to specific constructions, a small set of transitive verbs, or familiar verbs. Using the WWO paradigm, Abbot-Smith et al. (2001) found that English-learning 2;4-year-olds are more adept at identifying and correcting noncanonical word orders that are more frequently encountered in their input. Similarly, in a pointing task, German-learning 3;0-year-olds were more likely to apply the word-order rule to simple transitives compared to transitive relative clauses (Brandt et al., 2016). Other studies have shown that children struggle to enact reversible transitives with a wider range of verbs until around 2 and a half or 3 years of age (Akhtar & Tomasello, 1997; Olguin & Tomasello, 1993; Roberts, 1983; Tomasello, 1992). In addition, experiments following the WWO paradigm have found that verb frequency influences performance. English-learning children aged 2;4 and 2;9 are more likely to correct sentences with ungrammatical word orders if they contain a frequent verb, whereas 3;9-year-olds consistently use the canonical order regardless of verb frequency (Abbot-Smith et al., 2001; Matthews et al., 2005; also among children learning French: Matthews et al., 2007; Spanish: Aguado-Orea et al., 2019; see also results for Japanese by Chang et al., 2009).

Cross-linguistic research suggests that the acquisition of word order may even progress more slowly in languages with flexible word orders and argument ellipsis (e.g., Slobin & Bever, 1982). In the case of Mandarin and Cantonese, children develop an abstract understanding of the SVO word order as a cue for agent-patient relations at around age 3. These languages, which are SVO in nature, permit word order variation and argument omission. They have markers for objects and passive voice subjects, but lack agreement and case-marking morphology. For instance, in an act-out task with novel verbs, Cantonese learners exhibited above-chance selection of the first noun as the agent in SVO sentences at 3;6, but not at 2;6 (Chan et al., 2009). Similarly, in a preferential looking study, Mandarin learners matched the agent with the first noun more strongly at 2;9 compared to 2;0 (Candan et al., 2012; although concerns about measurement inconsistencies were raised by Zhu et al., 2022).

French, an SVO language with subject-verb agreement and some word order flexibility but minimal null arguments, exhibited similar results as Spanish and

Italian, also SVO languages with subject-verb agreement, but allowing subject-dropping and a higher degree of word order variation. Using the WWO paradigm with familiar verbs, 3;9-year-old French learners were found to still use ungrammatical orders (e.g., VSO, SOV), primarily with lower frequency verbs (Matthews et al., 2007). Similarly, Spanish learners at 3;10 still use ungrammatical orders (VSO, SOV) primarily with lower frequency verbs (Aguado-Orea et al., 2019). Italian learners, in act-out experiments with familiar verbs, exhibit a word-order strategy at 3;5 (Slobin & Bever, 1982) and 3;6, (Bates et al., 1984) interpreting NVN sentences as SVO. In contrast, English learners adopt this strategy as early as 2;6. By 4;6, both English and Italian learners apply a word-order strategy to NNV sequences previously interpreted randomly, with Italian learners extending it to VNN sequences (Bates et al., 1984).

In turn, Serbo-Croatian and German, both SVO languages with flexible word order, exhibit subject-verb agreement and case-marking on arguments (Serbo-Croatian) or determiners (German). In act-out comprehension studies with novel (Chan et al., 2009) and familiar verbs (Slobin & Bever, 1982), children showed comprehension of the canonical word order at 2;6 for German (Chan et al., 2009) and 3;3 for Serbo-Croatian (Slobin & Bever, 1982).

Turkish and Japanese are both SOV languages allowing word order variation and null arguments. However, Turkish has subject-verb agreement and argument case-marking, while Japanese uses case-marking particles to indicate grammatical relationships. A preferential-looking study by Candan et al. (2012) showed that Turkish children as young as 2;3 are sensitive to the canonical word order. However, Slobin and Bever's (1982) act-out task indicated that Turkish-learning children further develop their understanding of canonical SOV word order around 3;6. In the case of Japanese, Omaki et al.'s (2012) preferential-looking study found that Japanese learners struggle to understand sentences with canonical SOV order at 1;7, likely due to the frequent omission of case markers in child-directed speech (91%; see Matsuo et al., 2012) which hinders the identification of the canonical word order (see also Chang et al., 2009).

Word Order and Other Cues: Cross-Linguistic Evidence on the Relationship With Local Cues

In addition to word order, other cues contribute to a language's canonical transitivity schemas (Slobin & Bever, 1982). The interplay between these cues and word order explains the cross-linguistic variations in reliance on word order (Bates & MacWhinney, 1989; MacWhinney et al., 1985; Slobin & Bever, 1982; but see also Šagi, 2017). The following discussion focuses on the interaction between word order and local grammatical cues (see Section 2.3.1). While not discussed here, other influential cues include mixed grammatical cues (clitics and agreement), semantic cues (noun animacy), discourse cues (information structure), and phonological cues (stress).

Local Grammatical Cues: Case, Causative Morphology and Voice Markers. Case-marking on nouns, pronouns, and determiners can help identify transitivity schemas. However, there is an inverse correlation between case and constituent order as means of encoding grammatical function assignment (e.g., Fedzechkina et al., 2017). Studies with Turkish, Hungarian, and Polish children suggest that case-marking overrides word order in sentence interpretation. These languages have flexible word orders (with different canonical word orders: SOV in Turkish, SVO/SOV in Hungarian based on object definiteness, and SVO in Polish) and nominative and accusative case suffixes. Act-out studies with Hungarian learners aged 3;1, 4;0 and 5;7 (MacWhinney et al., 1985), Polish learners aged 2;6 and 3;6 (Weist, 1983), and Turkish learners aged 2;0 (Slobin & Bever, 1982) show that children interpret participant roles in transitive sentences guided by case-marking cues, paying little or no attention to word order. In the absence of case-marking, they resort to a first-noun-as-agent strategy. During a comprehension task involving elicitation, Özdemir-Yilmazer and Başol (2017) further found that older Turkish-learning children, aged 3;4 to 5;0, use the accusative marker to interpret OSV sentences but not SVO sentences. They also show a better understanding of verb argument structures with morphologically transitive verbs rather than lexically transitive verbs. Similarly, Spanish learners between the ages of 4 and 6 primarily rely on the case preposition "a" to interpret transitive sentences, as suggested by Kail and Charvillat's (1988) act-out study. However, word order affected latencies (shorter when both cues aligned: SVa-O).

Shin's (2021) forced-choice experiments revealed that Korean learners aged 4;1 and 5;11 rely on case markers, especially the nominative marker, when there is conflict between word order and case marking (e.g., OSV). They employ an agent-first strategy when word order aligns with either case marking or argument number. Korean is an SOV language with flexible word order, nominative and accusative markers, and possibility to omit arguments and case markers. In contrast, Japanese learners do not strongly rely on word order or particles alone. In act-out and imitation tasks, children between 2;3 and 6;2 pay attention to both the presence of the nominative particle -ga and its position in the sentence. Like Korean, Japanese is an SOV language with flexible word order and nominative and accusative case particles (Hakuta, 1982).

Other studies indicate that children still consider word order even when case-marking is present, although this may change with age. In an act-out study, Serbo-Croatian children (aged 3;3) heavily relied on word order, even in the presence of case inflections, and gradually learnt to consider inflections (Slobin & Bever, 1982). Similarly, Polish learners (aged 2;6 and 3;6) still occasionally misinterpreted non-canonical case-marked OVS sentences, indicating interference from word order cues (Weist, 1983). Both Serbo-Croatian and Polish are SVO languages with argument case-marking and word order variations.

Pointing experiments provide evidence for Czech, Hebrew, and German. These languages are SVO with word order variation and case marking in arguments

(Czech, Hebrew) or determiners (German). Like Serbo-Croatian and Polish, they present cases of case-marking ambiguity or are occasionally challenging to discern. Czech children comprehend SVO sentences more easily than OVS sentences at 3;8, but begin to interpret OVS sentences using case markers shortly after, at 4 (Smolík, 2015). Hebrew-learning children aged 4;0 rely on word order but prefer the object marker as they grow older (Sokolov, 1988). Evidence about the comprehension of transitive sentences by German-speaking children comes from act-out tasks (Lindner, 2003), pointing tasks (Brandt et al., 2016), or a combination of both (Dittmar et al., 2008a). Initially, they need converging cues to understand transitive sentences with novel verbs at 2;7 (Dittmar et al., 2008a) or use word order and case marking equally often at 3;0 (Brandt et al., 2016). At 3;6, they orient toward the initial NP if case-marking is ambiguous (Lindner, 2003) and rely more on word order than case marking at 4;6 (Lindner, 2003) and 4;10 (Dittmar et al., 2008). Although the positional strategy is also available at 5;6- and 6;6, it loses its influence thereafter (Lindner, 2003). Consequently, 6;8- (Brandt et al., 2016) and 7;3-year-olds (Dittmar et al., 2008a) use case marking and mostly ignore word order.

Additional evidence comes from Danish, Dutch, and English. While Danish and Dutch allow various word orders in transitive clauses, English is a strong SVO language. However, the three of them have limited case marking, primarily observed in personal pronouns. An act-out study showed that Danish learners (aged 5;6) rely on a word order strategy and misinterpret OVS constructions (Thomsen & Poulsen, 2015). Given that children were able to override this preference when provided with an appropriate discourse context, the authors suggested that children's understanding of case is still immature and relies on specific discourse contexts for being effectively exploited. Similarly, McDonald (1986) found that Dutch-learning children aged 7;5 and English-learning children aged 5;9- to 12;11 strongly relied on word order to interpret who or what had performed the action referred to by a stimuli sentence previously heard. Among Dutch-learning children, case inflection emerged as the last cue to be mastered and was weakly used compared to adults, who relied on it strongly.

According to a sentence completion experiment (Garcia et al., 2019), word order also takes precedence over morphosyntactic markers in young Tagalog learners (aged 5;9 and 7;8), who initially assume the first noun is the agent and need to rule this out before turning to morphosyntactic markers (but see ongoing evidence on Paiwan, a related language: Lin et al., 2022). Tagalog is a verb-initial language with flexible argument order, subject vs. non-subject markers on arguments and voice markers on the verb. The authors attributed this behavior to the agent's position and the omission of voice infixes in child-directed sentences.

Conclusion

In light of the reviewed literature, the number of nominals and word order hold importance in the development of basic grammatical schemas, particularly

in transitivity schemas within simple declarative sentences, regardless of the theoretical framework assumed. Research has shown that these cues impact children's comprehension of core grammatical structures, although their reliance on the number of nominals and word order varies across languages and is influenced by other available information such as case-marking, pragmatics, and input frequency.

However, the nature of the linguistic representations underlying children's performance remains a topic of considerable debate. Different methods imply distinct representations and processing demands in order to succeed in the experimental tasks. Computational models incorporate information on word order, the number of nouns, and other linguistic features to examine how children may acquire and interpret transitivity based on various cues. Therefore, they offer significant potential in unraveling the nature of the linguistic representations that aid children in accomplishing the laboratory tasks, and further exploration in this realm is warranted.

The reviewed studies predominantly employ preferential-looking designs, pointing, or other forms of selection experiments and act-out tasks to assess children's comprehension. The impact of the experimental methodology applied, given the specific requirements it imposes for children, should be thoroughly considered and openly discussed whenever findings are evaluated. In this way, differences in authors' perspectives regarding the task requirements may surface, encouraging scientific discussion. For instance, Dittmar (2008a) highlighted the challenging nature of act-out tasks, particularly their increased memory burden for small children. This is how the author explained the failure of 2;6-German-learning children to comprehend transitive sentences with novel verbs in act-out tasks, despite their success in pointing tasks. Conversely, Jiang and Haryu (2010, 2014) suggested that the use of act-out tasks may lead to an overestimation of children's knowledge of transitive and intransitive constructions. While act-out studies with 2-year-old English learners have shown knowledge of these constructions (e.g., Naigles et al., 1993), forced-choice pointing tasks have revealed that they still struggle to map an intransitive construction to a noncausative event (e.g., Arunachalam & Waxman, 2010). Thus, the authors claim that coding act-out tasks responses may lead to uncertainty, given the possibility that children may be focusing on the number of animals and picking up toys accordingly, rather than interpreting the abstract argument structure of the verb. Alongside open methodological discussion, replicating results across different methodologies for the same language is crucial to establish robust evidence. Currently, there are still sparse studies for a handful of languages using one or another methodology.

Lastly, assessing children's input with greater nuance is essential. Drawing firm conclusions about children's strategies and the sophistication of their grammatical knowledge requires considering more varied measures of their natural input. The grammatical properties of children's input can vary significantly across registers, activities, and participants, influencing the evidence children are exposed to. The reviewed studies, which primarily focus on children's input, predomi-

nantly examine child-directed speech by adults, overlooking other registers such as adult-directed speech or different speakers like peers. The activities through which the input is recorded are seldom mentioned or integrated into the reflection and discussion of findings. Recognizing that speech patterns vary significantly across activities and participants, this variability can profoundly impact the linguistic environment to which children are exposed daily and, consequently, their acquisition of transitivity constructions. A more comprehensive understanding of children's input can potentially enhance the accuracy and reliability of our conclusions regarding their linguistic representations of basic sentence structures, laying a solid foundation for further research.

Conflict of Interest Disclosure

The Author reports there are no competing interests to declare.

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Research Ethics Statement

In regards to this literature review article, it's important to clarify that institutional ethical approval was not necessary as no primary data was collected or analyzed.

Data Availability Statement

The data analyzed in this study is given in the Appendix, which has been uploaded to OSF and can be accessed using the following link: https://osf.io/w5hda/?view_only=bc5b6a4333604b25a5188915b7e35dc7

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