Mandarin Learners Use Syntactic Bootstrapping in Verb Acquisition

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Abstract

Mandarin Chinese allows pervasive ellipsis of noun arguments (NPs) in discourse, which casts doubt concerning child learners' use of syntax in verb learning. This study investigated whether Mandarin learning children would nonetheless extend verb meanings based on the number of NPs in sentences. Forty-one Mandarin-speaking two- and three-year-olds enacted sentences with familiar motion verbs. The presence of an extra post-verbal NP led the toddlers to extend causative meanings to intransitive verbs, and the absence of a post-verbal NP led them to extend noncausative meanings to transitive verbs. The effects of adding or subtracting an NP were statistically indistinguishable. Thus, the number of NPs in a sentence appears to play a role in verb learning in Mandarin Chinese.

Keywords

Verb acquisition; syntactic bootstrapping; Mandarin Chinese; language-general; cue to causativity; number of arguments

The Syntactic Bootstrapping hypothesis states that children use the syntactic frames in which verbs are placed to constrain their likely meanings as revealed by the context (Gleitman, 1990). Although considerable evidence exists that young learners exploit syntactic structure in learning verbs in languages such as English (e.g., Fisher & Gleitman, 2002; Naigles, 1990; Naigles & Swensen, 2007), the question remains whether syntactic bootstrapping is useful for the many other languages in the world that permit null arguments (e.g., Bowerman & Brown, in press; Narasimhan, Budwig, & Murty, 2005; Rispoli, 1995). Specifically, if a language allows pervasive ellipsis of noun arguments (NPs), then its syntactic frames, which are typically instantiated by differences in the number and arrangement of NPs, would seem uninformative for making conjectures about verb meaning. In this paper, we address this problem directly by considering the use of syntactic bootstrapping in one such language, Mandarin Chinese. Using an act-out task, we demonstrate that young Mandarin learners nonetheless use syntax as a source of information for determining verb meanings.

Syntactic bootstrapping works because the types of sentences in which a given verb can appear are at least partially a function of the meaning of that verb. For example, causative verbs (e.g.,

bring) typically appear in transitive frames (those with both a subject and a direct object), and noncausative verbs (e.g., *come*) typically appear in intransitive frames (those with a subject, but not a direct object) (e.g., Fisher, Gleitman & Gleitman, 1991; Jackendoff, 1990; Levin, 1993). These syntax-semantic correspondences then constrain the possible meanings of verbs children hear. Indeed, studies using intermodal preferential looking have demonstrated that 24- to 30-month-old English learners map novel verbs onto causative actions when given transitive sentences, and onto noncausative actions when given intransitive sentences (Fisher, 1996; 2002; Hirsh-Pasek, Golinkoff & Naigles, 1996; Naigles, 1990, 1996). Further evidence has found that by two and a half years of age, English-speaking children conjecture that a familiar verb placed in a novel frame has a new, predictable meaning (Naigles, Fowler, & Helm, 1992; Naigles, Gleitman & Gleitman, 1993). For example, young children enacted the sentence "*The pig goes the lion" to mean *the pig causes the lion to go*, but "*The pig brings" to mean *the pig comes*. Thus, they exploited the number of NPs in the sentence to extend the meanings of the verbs.

Recent research investigating children learning other languages has yielded similar findings. For example, five-year-old children learning French and three-year-old children learning Kannada were also able to use the number of NPs in sentences to extend causative meanings to familiar verbs presented in transitive frames and noncausative meanings to familiar verbs presented in intransitive frames (Lidz, Gleitman & Gleitman, 2003; Naigles & Lehrer, 2002). These findings do not yet speak to the problem of noun ellipsis for syntactic bootstrapping, though, because such ellipsis is rare in English and French and its prevalence in Kannada has yet to be established (Lidz et al., 2003).

Mandarin Chinese presents a "worst case scenario" for the use of syntactic bootstrapping in verb learning. That is, Mandarin Chinese allows the dropping of both subjects and objects in sentences in appropriate discourse contexts; moreover, it provides no morphological cues (i.e., nominal case markers, verbal causative markers) to the transitive/intransitive distinction in verb argument structure. For example, it is perfectly acceptable to say "*dai4*[1]/bring or carry" without mentioning either who is to do the bringing or what is to be brought (Lee & Naigles, 2005; Li & Thompson, 1981; Tiee, 1986). Analyses of maternal speech to Mandarin-learning toddlers have revealed that transitive verbs appeared with postverbal noun phrases (+NP) only 39% of the time while intransitive verbs such as *qu4*/go appeared with such NPs (as in *qu4 xue2xiao4* 'go (to) school') as much as 13% of the time. Thus, while the reliability of a +NP frame to indicate a transitive verbs was quite high (.83), the converse reliability of an absent post-verbal NP (-NP) to indicate an intransitive verb was quite low (.41) (Lee & Naigles, 2005).

These findings lead to two competing hypotheses concerning syntactic bootstrapping by young Mandarin learners. Following 'emergentist' or usage-based accounts (e.g, Tomasello, 2000), the transitive and intransitive frames should only be viable tools for syntactic bootstrapping in *older* learners because Mandarin input does not contrast these frames as categorically as in English. Indeed, the only demonstration of syntactic bootstrapping in Mandarin speakers thus far, that different 'translations' of novel verbs are provided depending on whether they had been presented in transitive or intransitive frames, has been reported only for children five years of age (Cheung, 1998, replicating Fisher, Hall, Rakowitz, & Gleitman, 1994). Moreover, children's behavior should match their input, with the effects of the +NP frame becoming evident earlier or more strongly than those of the −NP frame. Following more 'generativist' accounts (e.g., Lidz et al., 2003), the transitive/intransitive contrast should be a viable cue for syntactic bootstrapping for much younger learners—as young as two years, like those learning

[1]The numbers accompanying the Chinese words indicate which of four possible phonemic tones each word has. All Chinese pinyin and tones are based on *Xiandai Hanyu Cidian* 'Modern Chinese dictionary' (2001).

English—because they can rely on innate principles such as the theta criterion (i.e., a one-one relation between a verb's thematic roles and surface arguments; Chomsky, 1981). Moreover, the applicability of the presence versus absence of the postverbal NP should not be slavishly tied to the reliability of these cues in the input.

The primary purpose of the current study is to test these accounts of the onset of syntactic bootstrapping in Mandarin by comparing toddlers' interpretations of familiar verbs presented in one- versus two-NP sentence frames. If the number of NPs plays a role in very young children's verb interpretations, then 1-NP and 2-NP frames should yield different enactments. Specifically, transitive verbs should be enacted *less* causatively in 1-NP than 2-NP frames, and intransitive verbs should be enacted *more* causatively in 2-NP than 1-NP frames. In contrast, if Mandarin-learning toddlers have not yet learned the target relations between number of arguments and verb meaning–or if they have learned that their verbs do not vary in meaning depending on their appearance in 1- vs. 2-NP frames–then no differences should be found in their enactments of the same verbs in different frames. A second, weaker form of the usage-based hypothesis will also be tested: namely, the relative strength of the children's enactments should correspond to the relative strength of cues in the input. Specifically, because the '+NP ➔ transitive verb' cue is more reliable in Mandarin input than the '-NP ➔ intransitive verb' cue, the children's enactments of intransitive verbs in +NP frames should follow the frame more strongly than their enactments of transitive verbs in −NP frames (Thompson & Hopper, 2001).

Method

Participants

The participants included 18 children (eight boys) between the ages of 2;1 and 2;11 (mean = 2;8; SD = 3.29), and 23 children (13 boys) between the ages of 3;0 and 3;11 (mean = 3;8; SD =3.57). They were enrolled in daycare centers run by the Presbyterian Community Service in Singapore and came from Mandarin-speaking households. An additional six children (three two-year-olds and three three-year-olds) were excluded because they did not reach criterion with the fully-specified sentences (see below).

Materials and Procedure

The children were asked to enact sentences using a toy Noah's ark and its props (a boy, a girl, eight animals, and a small box). The sentences were designed by placing four transitive verbs (*dai4* 'bring', *na2* 'take', *tui1* 'push', and *fang4* 'put'), and four intransitive verbs (*lai2* 'come', *qu4* 'go', *zhan4* 'stand', and *dao3* 'fall') into two sentence frames. Frame 1 (NVN) was transitive and Frame 2 (NV) was intransitive (see Table 1). The stimulus set thus consisted of 16 sentences, in which each verb appeared in one NVN and one NV sentence. Aspect markers were omitted from the stimulus sentences so as to not provide additional cues concerning transitivity (i.e., *le* does not occur with verbs denoting ongoing actions such as *na2* 'take', and *zhe* does not occur with verbs that signal activity and cannot be used to describe a state such as *lai2* 'come' (Li & Thompson, 1981)); these markers are frequently dropped in Mandarin input as well (generally appearing with fewer than 20% of verb uses; Lee & Naigles, 2005). The sentences were presented in a two semi-random orders (randomly assigned across age and gender) such that no more than two sentences in a row contained the same verb or were of the same frame. Each child was introduced to the ark and props before enacting three pretest sentences (*qi2* 'ride' and *zou3* 'walk', presented intransitively, and *da3* 'hit' presented transitively) to familiarize her/him with the task. Prior to the test sentences, the children were told that some sentences might sound strange or funny; these should be enacted as best they could. All participants received praise after each practice and test enactment. The experimenter was careful to look at the children's faces during her production of the sentences, and during

the children's enactments, thereby not biasing either the number or type of animal used. The sessions were recorded for later coding.

Coding

The coding procedure was similar to the one used by Naigles et al. (1993). All enactments were first described using a detailed inventory of action descriptions, such as *Da4xiang4 tui1 xiao3gou3* 'Elephant pushes dog'. To establish a baseline for correctness, descriptions of transitive verbs in the NVN frame and intransitive verbs in the NV frame were coded for the correct animals, correct action, and correct use of subject and object in transitive sentences. Any child who failed to enact at least 80% of these sentences correctly was excluded from the analysis.

All enactment descriptions were then coded for *causativity*. The transitive sentences (e.g. *Xiao3zhu1 qu4/na2 shi1zi* 'The pig goes/takes the lion') were coded as causal if the pig *made* the lion go (e.g., NP1 acting on NP2 by pushing or carrying), and noncausal if the pig and lion went separately or the pig went *to* the lion. In contrast, the intransitive sentences (e.g. *Xiao3gou3 dai4/lai2* 'The dog brings/comes') were coded as noncausal if the dog moved alone, and causal if the dog brought/carried/pushed *something* (See Table 1). If the enactment did not fit into either of the two previous categories [i.e., the child used the wrong movement, animals, or agent-patient relation (NP2 acting on NP1)], it was coded as Other. Such enactments were rare, comprising 1% of all responses.

The enactments for all the sentences were initially described and coded by the first author. To determine the reliability of the coding procedure, an assistant described approximately half of the videotaped enactments without access to the stimulus sentences (she being a monolingual English speaker). This sample consisted of the entire set of enactments by 10 two-year-olds and 13 three-year-olds. Agreement between the two coders was 99.2%.

Results

To demonstrate syntactic bootstrapping, young Mandarin learners need to change their interpretation of the verb according to the number of NPs in the sentence frame. The percent of causative enactments was first entered into an omnibus ANOVA with Frame (NV, NVN) and Verb (transitive, intransitive) as within-subject variables, Age (2-year-olds, 3-year-olds) as a between-subject variable, and Gender as a covariate. Main effects of Frame [$F_{(1, 37)} = 373.24$, $p < 0.001$] and Age [$F_{(1,37)} = 5.35$, $p < 0.05$] were found. The interaction effects of Frame x Age [$F_{(1, 37)} = 7.82$, $p < 0.01$] and Frame x Verb [$F_{(1, 37)} = 175.36$, $p < 0.001$] were significant. No main or interaction effects involving Gender were obtained. Thus, the children's enactments varied by frame and by verb type, and the effects of frame were stronger for the 2-year-olds than for the 3-year-olds. Moreover, the effects of frame led to more causative enactments for the transitive verbs and fewer causative enactments for the intransitive verbs.

The key analysis, though, compares the same verb in 1- and 2-NP frames; that is, in grammatical vs. unattested frames, to demonstrate that each frame has an effect. Figure 1 shows that children from both age groups enacted *more* intransitive verbs causatively in the NVN frame than in the NV frame [2s: $t_{(1, 17)} = 4.35$, $p < 0.001$; 3s: $t_{(1, 22)} = 8.02$, $p < 0.001$]. Moreover, they enacted *fewer* transitive verbs causatively in the NV frame than in the NVN frame [2s: $t_{(1, 17)} = -7.16$, $p < 0.001$; 3s: $t_{(1, 22)} = -4.25$, $p < 0.001$] (see Figure 2). Thus, for both intransitive verbs in NVN frames and transitive verbs in NV frames, young Mandarin learners altered their enactments to fit the number of overt NPs in the sentence. Our analyses by items also revealed that these frame effects were significant for the four intransitive verbs [2s: $t_{(1, 3)} = 5.43$, $p < 0.05$; 3s: $t_{(1, 3)} = 4.30$, $p < 0.05$] for the two age groups. The frame effects for the four transitive verbs were also significant for the 2-year-olds [$t_{(1, 3)} = 5.71$, $p < 0.05$], and marginally

significant for the 3-year-olds [$t\,(1, 3) = 2.93, p = 0.06$]. Comparison of Figures 1 and 2 indicates that the extent of children's 'following the frame' was equivalent by verb type; that is, the change in the number of NPs in the stimulus sentences led to changes of approximately 40% greater or fewer causative enactments for intransitive and transitive verbs, respectively [$t\,(40) < 1$, ns].

Finally, these data were compared with those collected by Naigles et al. (1993) for English-learning preschoolers (19 two-year-olds, 20 three-year-olds), who enacted the same verbs in NVN and NV frames with the exception that they used the verb *stay* instead of *stand*. For intransitive verbs in the NVN frame, Naigles et al. (1993) reported percent causative enactments of 69.15 and 70.45 by their two- and three-year-olds, respectively; we conducted a 2 (Language) X 2 (Age) ANOVA which revealed only a significant main effect of Language [($F\,(1, 85) = 30.51, p < .001$]. Thus, the English learners enacted sentences such as **The zebra goes the lion* causatively more frequently than the Mandarin learners. For transitive verbs in the NV frame, Naigles et al. (1993) reported percent causative enactments of 34.63 and 60.00 for their two- and three-year-olds, respectively; this 2 X 2 ANOVA yielded only a significant main effect of Age [($F\,(1, 84) = 15.25, p < .001$]. Across language groups, then, the three-year-olds enacted sentences such as *The zebra brings causatively more frequently than the two-year-olds did.

Discussion

This study investigated Mandarin learners' use of the number of NPs in a frame when interpreting verbs. The investigation of Mandarin is particularly important because its pervasive ellipsis renders the number of NPs a weaker clue to the transitive/intransitive contrast. Our findings revealed that Mandarin learners changed their verb interpretations depending on the number of overt NPs in sentences.[2] That is, more intransitive verbs were causatively enacted in the 2-NP frames than 1-NP frames, and fewer transitive verbs were enacted causatively in the 1-NP frames than 2-NP frames. These transitive and intransitive frame effects were of equivalent strength, and replicate those already found for young English and Kannada learners (Naigles et al., 1993;Lidz et al., 2003).

These findings provide three counters to a solely usage-based account of the onset of syntactic bootstrapping in young children. First, the mere fact of demonstrating syntactic bootstrapping in two-year-old Mandarin learners indicates that the number of NPs provides a robust cue to verb meaning even when the input manifestation of this correlation is generally weak. Second, the more detailed differences in usage of postverbal NPs by verb type (Lee & Naigles, 2005) were not reflected in the children's performance, as the strength of the "1-NP noncausative" cue was no weaker than the "2-NP causative" cue. Thus, the use of number of NPs as a cue to causativity in early verb learning appears to be language-general rather than language-specific, appearing even in strongly elliptical languages such as Mandarin Chinese. Third, even though the syntactic cues to *both* transitivity and intransitivity are stronger in English than in Mandarin (i.e., The percent of +NP frames that include transitive verbs is .86 in English vs .83 in Mandarin; the percent of −NP frames that include intransitive verbs is .80 in English and .41 in Mandarin; Lee & Naigles, 2005; Naigles & Hoff-Ginsberg, 1995), Naigles et al.'s (1993) English learners showed stronger effects of syntactic frame with *only* the NVN frame, which was not the frame with the higher cross-language difference in language use. A usage-based account is unable to explain why Mandarin-learning two-year-olds, who have heard many instances of 1-NP frames with both transitive and intransitive verbs, should display such a strong 1-NP noncausative effect.

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[2]How children *should* treat verbs that are usually heard in both transitive and intransitive frames, according to the syntactic bootstrapping hypothesis, is treated in more detail in Gleitman (1990), Naigles (1996), and Bunger & Lidz (2005).

Our findings support the generativist account that the ability to use argument number as a cue to sentence meaning may be innate, as an outcome of Chomsky's theta criterion that two-participant relations tend to surface with two NPs while one-participant relations tend to surface with only one NP (Chomsky, 1981; Gleitman, 1990; Lidz et al., 2003). However, because behavior demonstrated by two-year-olds is not unarguably innate, these findings could also be attributed to young children's tendency to "regularize" probabilistic but not highly frequent patterns in their input (e.g., with probabilities of .3 to .6; Newport, 1999; Hudson Kam & Newport, 2005). That is, Mandarin learners might have observed the tendency of some verbs (e.g., transitive, causative ones) to appear with post-verbal NPs more frequently than other verbs (e.g., intransitive, noncausative ones), and generalized this to a rule even though the tendency was weaker than in English (i.e., 87% of transitive verb tokens appeared with post-verbal NPs in English (Naigles & Hoff-Ginsberg, 1995), vs. 39% in Mandarin). Both explanations thus require some kind of regularization imposed on the input by the child (Goldin-Meadow, 2003; Naigles, 2002). In sum, what the current findings demonstrate is that syntactic information that is not well-supported by the input is nonetheless used by young Mandarin speakers in the early process of verb learning.

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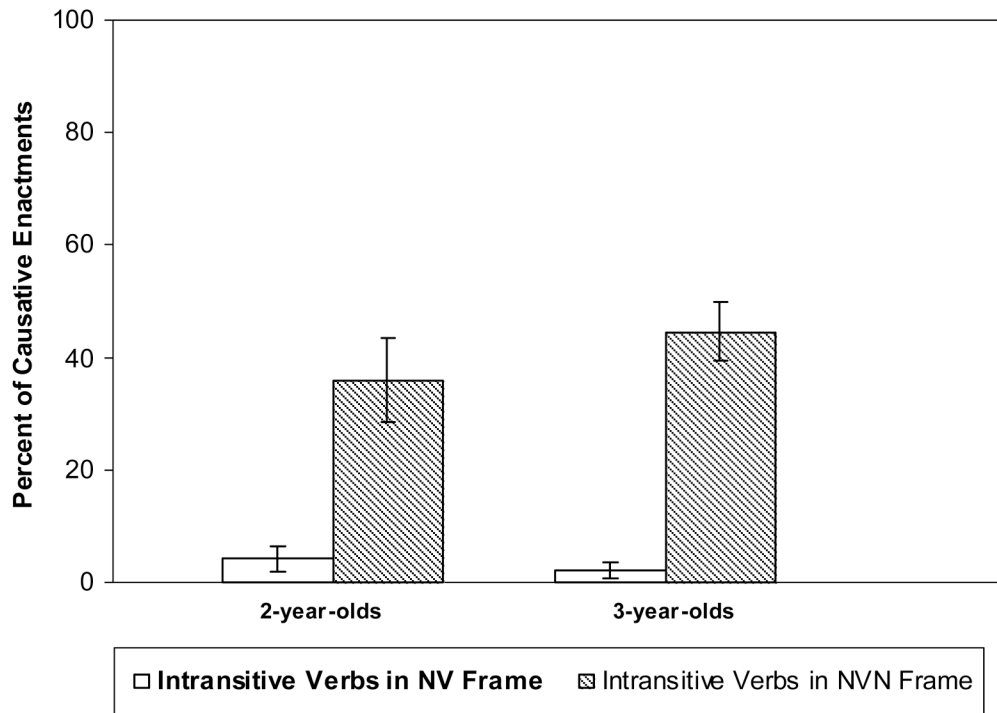Tomasello M. Do young children have adult syntactic competence? Cognition 2000;74:209–253. [PubMed: 10640571]

Figure 1.
Percent of Causative Enactments of intransitive verbs by Age (2- and 3-year-olds) and by
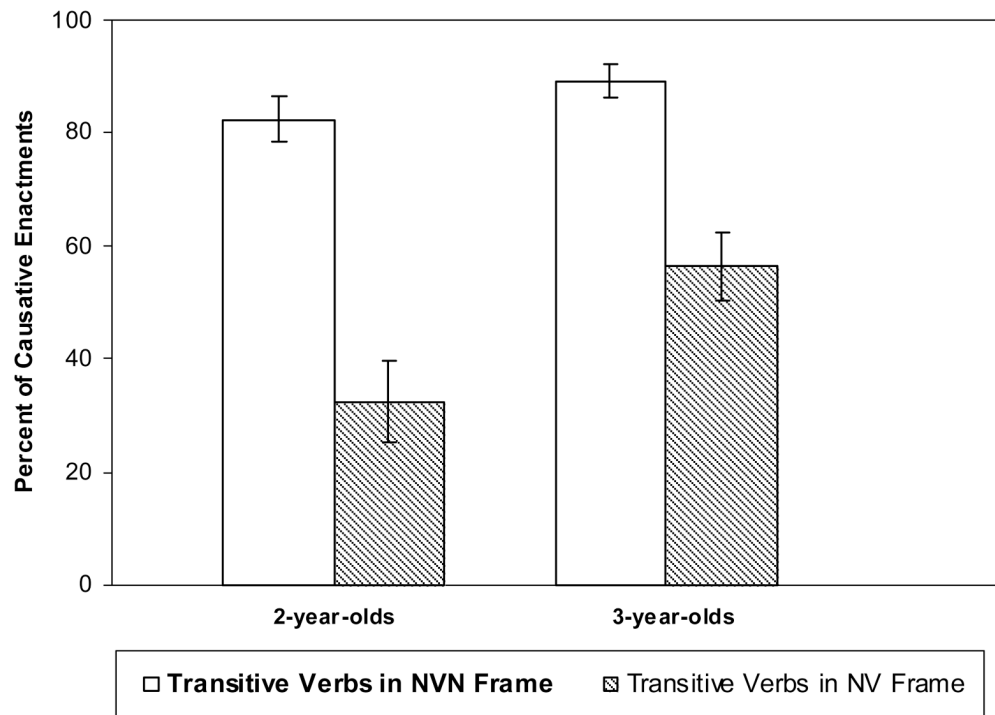Frames (NV and NVN).

Figure 2.
Percent of Causative Enactments of transitive verbs by Age (2- and 3-year-olds) and by Frames (NVN and NV).

Table 1

Sample Test Sentences[*]

Sentence Frame	Intransitive verb	Transitive verb
NVN	Xiao3zhu1 *qu4* shi1zi/ The pig *goes* the lion. Causal enactment: The pig pushes or carries the lion Noncausal enactment: The pig goes to the lion or the pig and lion go separately.	Xiao3zhu1 *na2* shi1zi/ The pig *takes* the lion.
NV	Xiao3gou3 *lai2*/ The dog *comes*.	Xiao3gou3 *dai4*/ The dog *brings*. Causal enactment: The dog pushes or carries an introduced animal or box Noncausal enactment: The dog moves alone.

[*] The target verb is in italics.