# Acquisition of Recursion in Child Mandarin

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## 1. Background

Recursion is the core of language ability.[1] Every language exhibits recursion from the first stage of productive two-word utterances because elementary Merge entails recursion. However, Category Recursion (Chomsky, Gallego, & Ott, 2019) or Indirect Recursion (Snyder & Roeper, 2003) shows extensive language variation: English and German compounds, and adjectives, are recursive to the left, but French allows no adjective or compound recursion on the left, (except non-recursive lexical exceptions). English, but not German, allows left-branching possessives. German, but not Swedish has a lexical restriction to Proper Names for the Saxon Genitive: *Maria's Haus* ('Maria's house') but not **Maria's Freund's Haus* ('Maria's friend's house'). Dutch appears to be variable in how much non-Proper Nouns are allowed (neighbor, for instance) (Merx, 2016). Romanian does not allow recursive PP's. Kalmak allows single complements, but does not allow recursive ones. Germanic has recursive compounds ('coffee-maker-maker'), but not Romance. Therefore, an acquisition challenge exists: the child must acquire – must select – his grammar from a large range of alternatives. Grasping the acquisition path for recursion across diverse language types is a formidable theoretical challenge, still in its infancy.

We focus on one corner in a growing literature on possessive recursion – Chinese and English – each of which is morphologically marked:

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[1] Hauser, Chomsky, and Fitch (2002), Snyder and Roeper (2004), Amaral *et al.* (2018), Roeper and Speas (2014) and many references therein. The issue has been controversial since a critique by Everett (2009). See recent commentary by Everett and Gibson (2019), and Hornstein (2019), and subsequent critique of Everett and Gibson by Rodriques (2019).

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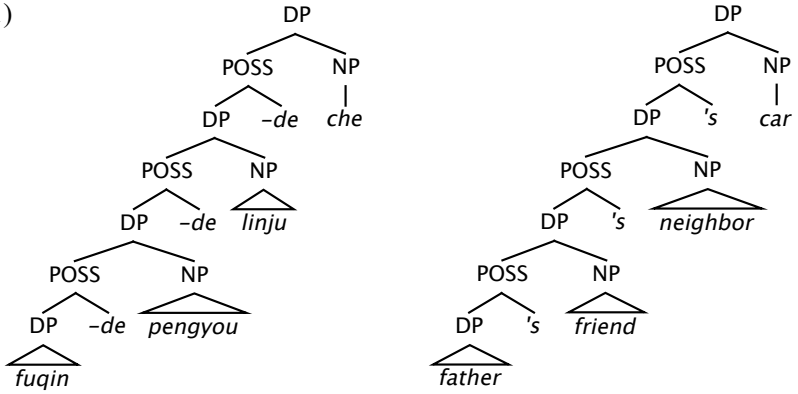
(1)




What enables children to see that category recursion (e.g. DP) is possible? There are several possible avenues. The first is the experience of recursion itself. In fact, children experience many instances of recursion and produce it as well from the age of 2yrs.

**Table 1. Children's early production of recursion**

| Corpus | Child age | Utterance |
|---|---|---|
| Manchester | 2;0.15 | "Anne's Mum's dolly" |
| Manchester | 2;3.28 | "Ellie's Daddy's" |
| Roeper | 3;1 | "you're my Mom's Mom" |

In earlier work (Hiramatsu *et al.,* 1999) it seemed that adult input on recursion was very sparse. These child examples strongly suggest that adults are using these 2-level forms of recursion in English, though none arise in German.

There are 3-level cases in the input as well (from a typical family game (childes (see Roeper, 2007))): "what is your Mom's cousin's name?" Or experimental games like: "Do you know who your grandma's son's sister's son is? ( => "me")" are not baffling for most children (See Sybsma, in preparation). Giblin *et al*. (2019) shows that children can produce two-level possessives from 4yrs experimentally where contrastive stress is also engaged.[2]

In addition, other forms of recursion may invite (or trigger) these extensions. Sevcenco *et al*. (2015) show recursive PP's and Relative Clauses at 4yrs in both

[2] Children successfully interpret recursion involving possessives, PPs, and RCs by age 6, often earlier (e.g., Limbach & Adone, 2010; Pérez-Leroux et al., 2012; Sevcenco et al., 2015). 3-to-4-year-old children tend to interpret recursion as conjunction and to drop embedded DPs (e.g., Limbach & Adone, 2010; Roeper, 2011), which fits results below.

comprehension and production and children who can do one can generally do the other.

While these data are very suggestive, evidence and the experiment below suggests that the shift from 2-level to 3-level possessives is more difficult. Why? One might suggest general processing difficulty, but 3yr-olds are known to produce and comprehend extensive recursive relative clauses as in the nursery rhyme: "this is the cat the chased the rat that ate the cheese that....". The existence of nursery rhymes with outspoken recursion suggests that folk wisdom already knew that children need exposure to recursive expressions and their meanings.

How exactly then do children recognize recursive potential for each structure? Pérez-Leroux *et al.* (2018) and Yang (personal communication, November 11, 2019) have suggested that pure productivity of single possessives (*John's bike*) could warrant recursive forms. Productivity of simple possessives no doubt plays a critical role in isolating the syntactic category N from associated semantic factors or features that do not participate in UG syntactic recursion. Since German (but not Swedish) limits possessives to Proper Nouns, the extra feature beyond the N category arguably prevents formation of the purely syntactic rule. Productivity supplies a diverse set of examples should which then isolate the fact for the child that only a Noun is needed to participate in the rule expansion: NP => [POSS DP 's].

Other distinctions are present in the data. Semantic classes may add features such as *inalienable possessives* – a default semantics for bare nouns in Japanese (Terunuma *et al.*, 2017), which might or might not block recursion. We will discuss *generics* as another relevant class.

### 1.1. Two kinds of Recursive Possessives

While exposure to recursive possessives is an obvious trigger and children no doubt hear them because they produce them at 2yrs, as we have seen, a more careful look at possessives suggests that two recursive elements may be insufficient because they are not necessarily semantically uniform, leading to the possibility that they are separately generated and therefore not jointly recursive.

Munn (1999) considers examples like:

(2) Bloomingdale's men's clothing

which reveal that apparently recursive possessives can involve both a generic (men's) and a definite reference (Bloomingdale's). Moreover, they can be independently recursive:

(3) men's clothing's color is usually pale.

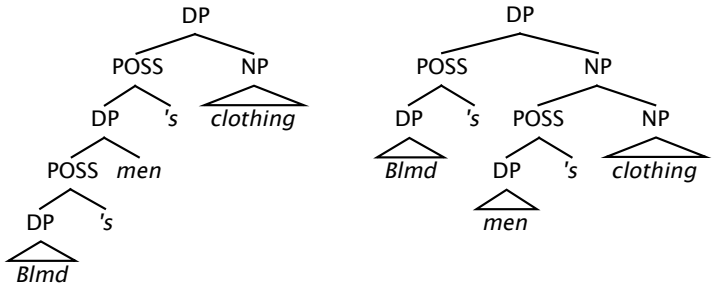
And evidence from 2yr olds strongly suggests that generic possessives are recognized:

**Table 2. Children's early production of generic possessives**

| Corpus | Child age | Utterance |
|---|---|---|
| Shem | 2;8.03 | "I'm gonna have a little kid's spoon" |
| Manchester | 2;8.06 | "I go on big girl's swings" |

Munn (1999) therefore argues for two Poss positions with the following form:[3]

(4) a. recursive: DP – NP b. non-recursive: DP (DP)




If generics are ambiguous, the child could generate two possessives with no recursion. An additional dimension with which the child must cope is that German and Chinese, as well as English, generate comparable generic meanings with compounds like these English ones (*doghouse, mousehole*) or sometimes adjectives (*American forces*). Nevertheless, if two positions are a universal option, then they could be an option in any language.

Consequently, it is 3-level recursive input that would unambiguously guarantee that the child must project a recursive structure[4].This is not so implausible if one argues, as Yang does, for instance, that comparisons of small amounts of data are critical in separating regular from exceptional phenomena. Sentences like *look at my Mom's friend's hat* are not so unusual and therefore a minimal amount is presumably available. Since individual words are acquired with few examples,[5] the same could hold for new structures. For instance, German allows multiple recursive modals while in English it is possible only in dialects

[3] These are found in Hindi as well (R. Bhatt, personal contact).

[4] Giblin *et al.* (2019) purport to offer a different analysis "Of course, questions remain about how adult speakers of German block Level 2 Genitives of the kind witnessed in English and Mandarin. The main point, however, is that children acquiring English and Mandarin manifest recursive nominals early and in the absence of decisive input". This approach does not explain why most languages do not have recursive genitives if no input is necessary. Obviously French does not have left-hand recursive possessives because it has no left-hand possessives. So at least one possessive is needed as input.

[5] S. Carey (2009) argues that children, who have a vocabulary of about 100,000 words by age six, learn them at the rate of one an hour. They cannot involve many examples. Idioms and syntactic structures could be swiftly represented in the same way.

(*might could, might should, should could*, etc.) with highly variable frequency (some allow only *might could*). Again, recursion should enter the grammar with the presence of a single modal in English if its high productivity is the only requirement (a child certainly hears hundreds of sentences with modals every day). Under the view that recursion is a UG option that is found in some form in every language and therefore triggered with minimal information, even if the information is fairly subtle, the critical data may involve more than single instances of possessive.

### 1.2. Phrasal Possessives

There are further possible more indirect sources of evidence for recursion. The formulation of recursion allows a possessive marker to introduce another DP with its own Possessive.

(5) DP => Poss NP, NP => N (PP), PP => P (DP)
Poss => {my, your, DP} 's

This allows: *John's friend's hat*, but also a phrasal phrase like:

(6) [the man on the corner]'s hat]].

Any complex DP like (6) therefore would serve as evidence that recursion is possible because the rule can generate it. Informal experiments with 4yr olds suggests no comprehension problems with sentences like *Point to the dog next to me's hat* in contrast to *the dog next to my hat*, although further experiments would be useful.[6]

### 1.3. Morphological Recursion

A third relevant factor is morphological iteration: the child recognizes within adjacent domains a common morphology that can therefore be co-indexed. Any form of morphology that is repeated under c-command structure is open to binding algorithms which in turn could be an invitation to a recursive interpretation. It is evident in English and Chinese that the morpheme marking possessive is repeated: *de....de....de* or *'s... 's... 's*. Nakato, Nelson, and Roeper (2018) attribute the earlier recognition of locative PP recursion in Chinese over English to the presence of a repeated morpheme.

The identical morphology in turn permits an identical intonational emphasis as in cases like:

[6] It is difficult to isolate such cases in naturalistic data but one example is known from a 5yr old: *the one with long hair's picture.*

(7) this is the cat that chased the mouse that ate the cheese[7]

Once recognized, by whatever combination of information, the recursive system allows an embedded interpretation such that – unlike conjunction that gives separate interpretations – an expression like:

(8) John's friend's hat

gives a *cumulative* single possessive (only the friend's hat), not conjoined individual ones (John's and friend's hats), in an efficient manner. Ultimately in languages like English, recursion for PP's is linked to the syntactic PREP category (label) itself since there is no special morphology. This correlates with later acquisition PP-recursion in English than in Japanese (which has the no- particle) and we expect in Chinese.

In the following experiment we explore 2 and 3 level recursive acquisition of possessives in Chinese. As stated above, similar to those in English, recursive possessives in Mandarin Chinese can be embedded multiple levels as left-branching recursion, and are morphologically marked. Yet a difference between English and Mandarin Chinese in terms of the expression of possessiveness is that pre-nominal possessives are the only way in Mandarin to denote possessiveness, while English can use both pre-nominal possessive phrases (*father's friend*) and post-nominal prepositional phrases (*friend of father*), so when expressing multiple levels of possessiveness in one phrase, Mandarin has to use recursive possessives, while English can also avoid recursion by alternating between possessives and PPs (*car of father's friend*). In the next section we show that the experiment finds that 4yr olds show clear knowledge of recursion in 3-level possessives, but that they exhibit a striking difference between 2 and 3-level possessives, consistent with the argument we have made that more complex input information is required. Many further comparisons with other languages and other structures are needed to fill in the picture for the acquisition path for recursion.

## 2. Experiment

### 2.1. Participants

Thirty children in ages between 3 and 6 years participated in the experiment. They were divided into two age groups: 4-year-olds ($N$ = 10, $M$ = 4;0, range = 3;4 – 4;3) and 6-year-olds ($N$ = 20, $M$ = 5;11, range = 5;4 – 6;4). The children were recruited from Jiehua Kindergarten of Tsinghua University. All of them were monolingual speakers of Mandarin. No participant had any history of speaking or hearing difficulties or cognitive impairment.

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[7] Note that where there is no overt morphology, the recursive relative may verge on ungrammaticality:

i. ?? this is the rat the cat chased to the monkey the lion put near the dog the horse likes.

### 2.2. Procedure and Task

The task consisted of a familiarization phase and a test phase. In this section, the experimenter showed the child pictures that depicted possessive relationship, described the pictures with recursive possessives, and asked the child to repeat the recursive possessives. The recursion level was built up gradually in each picture to guide the child through the section. For example, in the sample picture for familiarization phase shown in Figure 1, the experimenter described the possessive relationship as follows: "Look! There is a robot [point to the robot]. The robot has a snake [point to the snake]. So this is the robot's snake. The snake has a lion [point to the lion]. So this is the robot's snake's lion. The lion has a cookie [point to the cookie]. So this is the robot's snake's lion's cookie." Every time the experimenter introduced a new recursive possessive (i.e., robot's snake, robot's snake's lion, robot's snake's lion's cookie), she asked the child to repeat it. There were three such pictures in total in the familiarization phase. The child then entered the test phase regardless of whether his or her repetitions were correct.

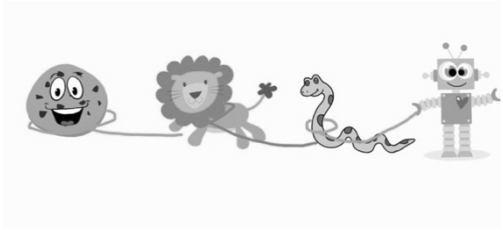

**Figure 1. Sample picture for the familiarization phase**

The test phase adopted an act-out task. In this phase, the child was presented with pictures showing possessive relationships similar to those in familiarization phase, and was instructed by the experimenter to give a little object to a certain character according to the recursive possessive sentence they heard from the experimenter. The experimenter first introduced all characters in the picture and their possessive relationship without using any recursive possessives to avoid the priming effect. For example, for Figure 2, the introduction was: "Up here there is a robot. The robot has a lion. The lion has a snake. The snake has a cookie. Down there, there is also a robot. The robot has a snake. The snake has a lion. The lion has a cookie." Then the experimenter instructed the child to give leaves to characters described by one-, two-, or three-level recursive possessives. Sample test items are shown in (9).

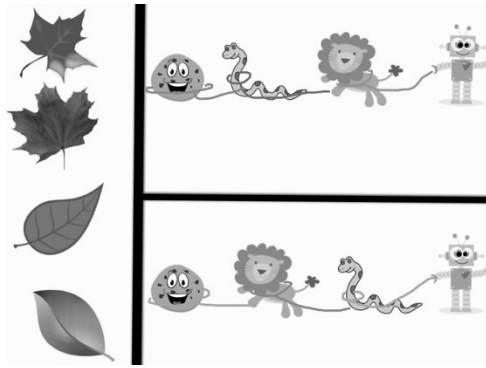

**Figure 2. Sample picture for the test phase of recursive possessive task**

(9) a. one-level possessive:
she-de shizi
snake-GEN lion
snake's lion
b. two-level possessive:
jiqiren-de shizi-de she
robot-GEN lion-GEN snake
robot's lion's snake
c. three-level possessive:
jiqiren-de she-de shizi-de binggan
robot-GEN snake-GEN lion-GEN cookie
robot's snake's lion's cookie

There were two one-level test items, five two-level test items, and five three-level test items, making up a total of 12 test times. Throughout the test phase, the child was complimented for participating, regardless of the accuracy of the responses. The experimenter would not correct the child if the child made errors.

The experiments were conducted and recorded in the iPad software *Explain Everything*, which enabled image creation and movement, and audio- and screen-recording. The tests were carried out individually in a quiet room at the kindergarten, and lasted for around ten minutes for each child respectively.

### 2.3. Results

Children's answer in the act-out task was coded as one of the following: recursion, conjunction, reduction, or other. Recursion is the correct answer. Conjunction means children interpret recursive possessives as conjunctive structures, i.e., they assign an 'and' interpretation instead of a possessive reading. Reduction means children omit one or more embedded DPs in the recursive structure they hear. All other types of errors were coded as 'other'. Table 3

illustrates how children's different choices of characters were coded when hearing *robot's lion's snake*.

**Table 3. Coding of answers to 'robot's lion's snake'**

| Children's answer | Coding |
|---|---|
| robot's lion's snake | Recursion (correct) |
| robot, lion, and snake | Conjunction (error) |
| robot's snake | Reduction (error – dropping 'lion') |
| lion's cookie | Other (error) |

**Table 4. Percentage of types of answers**

| Participant group | Possessive level | Recursion (correct) | Conjunction (errors) | Reduction (errors) | Other errors |
|---|---|---|---|---|---|
| 4-yrs | 1 | 75% | 5% | 10% | 10% |
| | 2 | 54% | 12% | 26% | 9% |
| | 3 | 46% | 14% | 30% | 10% |
| | All | 64.17% | 11.67% | 25% | 9.17% |
| 6-yrs | 1 | 80% | 0 | 17.5% | 2.5% |
| | 2 | 76% | 9% | 11% | 4% |
| | 3 | 72% | 16% | 4% | 6% |
| | All | 75% | 10.42% | 9.17% | 5.42% |

Table 4 summarizes children's responses. Repeated-measures ANOVA found a significant effect of answer type (**$p < .01$) but no effect of age ($p = .757$). Post-hoc Tucky test found significantly more recursive answers than other answer types (**$p < .01$) and reduction more frequent than other errors but conjunction (**$p < .01$). For 4 year olds, recursion exceeded errors other than conjunction and reduction ($p$** $< .01$). For 6 year olds, recursion exceeded all errors (**$p < .01$). Among all answer types, between-subjects effect was only significant for reduction: 4 year olds dropped DPs more frequently than 6 year olds (*$p = .027$)

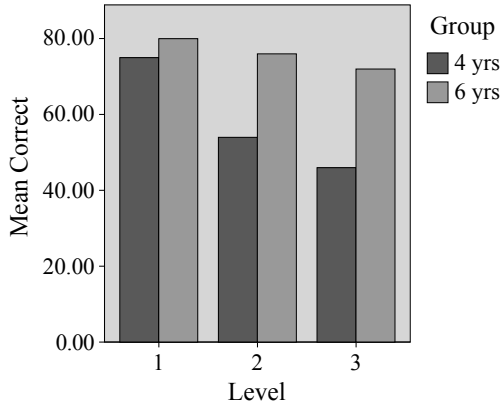


**Figure 3. Percentage of recursive (correct) answers of 4- and 6-year olds per level**

Figure 3 illustrates children's accuracy rate broken down by age group and recursion level. Overall, there is no effect of age group ($p$ = .125) but a negative effect of recursion level (*$p$ = .023), i.e., children gave fewer accurate responses when recursion level increased. Pairwise comparisons found significantly higher accuracy rate at one-level than at three-level (*$p$ = .035). Within each age group, there is no difference on accuracy rate across recursion levels (4 year olds: $p$ = .060; 6 year olds: $p$ = .460). Between-subjects difference is significant only at three-level: 6 year olds gave more correct answers than 4 year olds on three-level recursive possessives (*$p$ = .041).

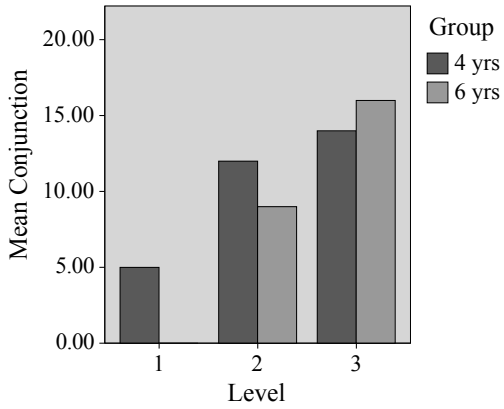


**Figure 4. Percentage of conjunctive answers of 4- and 6-year olds per level**

Children's conjunctive answers are shown in Figure 4. Repeated-measures ANOVA showed no effect of age group ($p$ = .741) but a significant effect of recursion level (*$p$ = .013). Pairwise comparisons show that children gave

significantly more conjunctive answers at three-level than at one-level (*$p$ = .026). Within each age group, four year olds show no difference on conjunctive answers across recursion levels ($p$ = .266), while six year olds gave significantly more conjunctive answers at three-level than at one- (*$p$ = .023) and two-level (*$p$ = .046). At each recursion level there is no between-subjects difference in conjunctive rate.

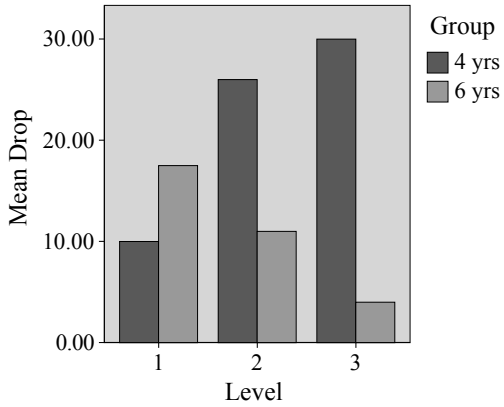


**Figure 5. Percentage of reductive answers of 4- and 6-year olds per level**

Figure 5 shows children's reductive answers. Repeated-measures ANOVA found no effect of recursion level or age group, but a significant effect of recursion level * age group (*$p$ = .011), i.e., as recursion level increases, four year olds gave more reductive answers, but six year olds gave fewer reductive answers. Between-subjects difference is significant only at three-level: 4-year-olds gave more reductive answers than six year olds at three-level recursive possessives.

Furthermore, an examination of individual performance revealed that when we set giving the correct answer 60% of the time as the standard, then all 6 year olds were either good at both 2- and 3-level tasks or bad at both levels; whereas 30% 4 year olds were good at 2-level but bad at 3-level tasks.

### 3. Acquisition Path Contrast

The earliest evidence in Gentile (2003) led to the surprising conclusion that there was a big difference between 2 level possessives and no difference between 3 and 4 level possessive recursion. That result is reappearing with completely different scenarios and languages and parametric environments (left and right branching languages). These connections are what we should expect when the deepest abstract principles are at work.

The sharpest contrast in response pattern occurs in Table 4 where 30% of 4yr olds show reduction for the 3-level recursive cases – the delete one element, while only 4% of 6yr-olds show reduction for the most complex case and more for the 1 or 2-level cases. This suggests that whether they have conjunction or recursion,

the older children are responding with a grammatical representation and not a performance-based shortcut by the age of 6yrs. This in turn supports the view that the conjunctive response is a grammatical representation on the acquisition path, found in many experiments (Sevcenco *et al.,*2015; Terunuma *et al.*, 2017) reaching back to early work by Tavakolian (1981) on conjunctive responses to relative clauses.

What does the larger picture reveal? These results fit the pattern for early steps with adjectives (Matthei, 1981), Tero, in preparation), compounds (Hiraga, 2010), and sentence complements (de Villers *et al.,* 1990) and others. Nonetheless the evidence is allowing us to envision the micro-steps along this path and the fashion in which other grammatical factors complicate the picture, causing, for instance the possibility that non-recursive representations at the 2-level forms, like the presence of both generic and referential possessives, mean that decisive evidence of recursion is less clear, and the challenge for the child of discriminating productive from exceptional phenomena remains significant and intricate.

Another observation is that that comprehension of recursive possessives seems to be easier for Mandarin-speaking children than for English-speaking children. In Gentile's (2003) study, about one third of three-to-four-year-old English-speaking children interpreted two-level recursive possessives as conjunction, whereas in the present study four-year-olds only gave conjunctive answers 12% of the time at two level. Limbach and Adone (2010) reported that the accuracy rates for English-speaking children average aged 3;7 and 5;7 in two-level recursive possessive comprehension tasks were 56% and 59% respectively, with reduction rate 25% and 15% and conjunction rate 9% and 22% for the two age groups. While the data from the younger group were comparable to those of the four-year-olds in the present study, the older children in Limbach and Adone's (2010) study gave obviously fewer correct answers and more conjunctive answers than their Chinese peers (recursion: English 59% vs Mandarin 76%, conjunction: English 22% vs Mandarin 9%). This might arise from the face that Mandarin only uses prenominal-possessives to denote possessiveness, whereas English can alternate between pre-nominal possessives and post-nominal PPs. This suggests another aspect that could influence the acquisition of recursion.

The behavior of the *de-* particle in Chinese, and a comparable one in Spanish and Romanian, and the *no-* particle in Japanese suggests that the morphological component is an essential feature of the analysis whose theoretical role remains to be fully articulated.

## 4. Conclusion

We are beginning to see some subtle angles on how the core of grammar is realized within the huge range of daily experience of a child. We are exploring the complexity of one variety among many where the core operation of generating recursive structures – and computing their meaning (see Pérez-Leroux *et al.*, (2018)) – is like a slender but systematic skeleton within the complex surface of

grammar. Despite the subtlety and relative rarity of critical information, children are able to efficiently identify recursion because UG tells them it should be there.

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