

Children's Knowledge of Disjunction and Universal Quantification in Mandarin Chinese*

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Downward entailing linguistic environments license inferences from sets to their subsets. These environments also determine the interpretation of disjunction: Disjunction licenses a conjunctive entailment in the scope of downward entailing operators (Crain 2008, 2012). This leads to a striking asymmetry across languages in the interpretation of disjunction when it appears in the restrictor (downward entailing) versus the nuclear scope (non-downward entailing) of the universal quantifier such as English *every* and Mandarin *mei*. The present study investigated Mandarin-speaking children's interpretation of the disjunction word *huozhe* in sentences with the universal quantifier *mei*. The main findings were that young Mandarin-speaking children assigned the conjunctive entailment to *huozhe* when it appeared in the restrictor of *mei*. Moreover, they allowed the disjunctive truth conditions of *huozhe* in the nuclear scope of *mei*. Altogether, children's asymmetric responses in the two arguments of *mei* suggest that Mandarin-speaking children, like adults, are aware of the semantic property of downward entailment at an early age. Along with previous cross-linguistic studies, the findings of the present paper provide further evidence for the view that the semantic 'core' property of downward entailment (a) applies in different linguistic communities, and (b) appears at an early stage of language development.

Key words: downward entailment, disjunction, universal quantification, language acquisition, Mandarin Chinese

1. Introduction

All things being equal, a putative universal linguistic property is expected to be manifested in typologically different languages and to emerge early in the course of language development. For core properties of Universal Grammar (UG), this is the null

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hypothesis, to be abandoned only in the face of disconfirming evidence. It follows that cross-linguistic research is a prime testing ground for proposals about universal properties of human languages. Another prime testing ground is child language. The present study adopts this dual approach in assessing one candidate for a universal semantic property, downward entailment.

Some features of downward entailment have already been addressed in previous child language research, including several cross-linguistic studies in English, Japanese, and Mandarin Chinese (e.g. Goro & Akiba 2004, Notley, Zhou, Jensen & Crain 2012, Su, Zhou & Crain 2012; see Crain 2008, 2012 for reviews). The present study pursues this line of research by assessing Mandarin-speaking children's interpretation of the disjunction word *huozhe* 'or' in the two arguments of the universal quantifier *mei* 'every'. Across languages, disjunction (inclusive-*or*) generates a more restricted set of truth conditions when it appears in the scope of downward entailing expressions, as compared to non-downward entailing expressions (Crain 2008, 2012). This leads to an asymmetry in the interpretation of disjunction when it appears in the (downward entailing) restrictor versus the (non-downward entailing) nuclear scope of the universal quantifier. Children's knowledge of this asymmetry has been tested in previous English studies (Boster & Crain 1993, Gualmini, Meroni & Crain 2003a, 2003b), yet it remained rarely explored in typologically different languages (but cf. Su et al. 2012). The primary goal of this study is to assess whether or not the asymmetry in sentences with disjunction and the universal quantifier is demonstrated across languages, and emerges early in language development. If so, this will be taken as further evidence for downward entailment as an innately specified linguistic property (see e.g. Crain & Pietroski 2002, Crain, Gualmini & Pietroski 2005, Crain, Thornton & Khlentzos 2009). The second goal is to offer these empirical investigations as a useful yardstick for assessing alternative models of language acquisition.

The structure of the paper is outlined as follows. We first describe the defining and diagnostic properties of downward entailment. Then, we address the issue of language learnability, namely how children acquire the different truth conditions for disjunction in the two arguments of the universal quantifier. Next, we review previous cross-linguistic studies on downward entailment in child language. Afterwards, we report our two experiments on Mandarin-speaking children's interpretation of *huozhe* in sentences with the universal quantifier *mei*. Finally, we present the concluding remarks.

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2. The properties of downward entailing operators

There are three hallmarks of core linguistic properties. First, these properties should be manifested across human languages. Second, they should unify several linguistic phenomena that, on the surface, appear unrelated. Finally, they are expected to emerge early in the course of language development. Applying these hallmarks, the semantic property of downward entailment is a viable candidate to be considered as a core linguistic property. First, downward entailing expressions appear in all of the world's languages, as far as we know. Second, downward entailing expressions tie together superficially unrelated facts, such as the distribution of negative polarity items (e.g. English *any*), as well as the special truth conditions that are associated with disjunction in downward entailing linguistic contexts. Finally, knowledge of downward entailment appears in children younger than three, across languages (cf. Crain & Khlentzos 2008).

The defining feature of downward entailing operators is that they license inferences from sets to their subsets (e.g. Ladusaw 1979). For instance, in the scope of a downward entailing operator, if a sentence that contains the set-referring expression 'a (musical) instrument' is true, then so is a sentence in which that term is replaced by one that refers to one of its subset items, e.g. 'a violin' or 'a clarinet'. Based on this definition, it can be seen that the examples in (1) and (2) contain downward entailing operators, because if the (a)-examples are true (with the set-referring term), then so are the (b)-examples (with the subset-referring term). Example (1) shows that the prepositional phrase headed by *before* is downward entailing. Example (2) shows that the predicate phrase of the negative quantificational expression *nobody* is downward entailing.

- (1) a. Amy listened to the tape before playing an instrument.
b. \Rightarrow Amy listened to the tape before playing the violin.
- (2) a. Nobody at this table learned to play an instrument.
b. \Rightarrow Nobody at this table learned to play the violin.

It is noteworthy that these two examples are each members of a minimal pair, where the other member of the pair is not downward entailing. Specifically, the following linguistic contexts are non-downward entailing: the prepositional phrase headed by *after* and the predicate phrase of the positive quantificational expression *everybody*. As illustrated in examples (3) and (4), these non-downward entailing contexts do not validate the inferences from sets to the subsets. We shall have more to say about these match-ups in due course.

- (3) a. Amy listened to the tape after playing an instrument.
b. $\ast \Rightarrow$ Amy listened to the tape after playing the violin.
- (4) a. Everybody at this table learned to play an instrument.
b. $\ast \Rightarrow$ Everybody at this table learned to play the violin.

One diagnostic of a core linguistic property is that it unifies apparently disparate linguistic phenomena. Accordingly, downward entailing operators play a prominent role in several linguistic phenomena that, at first glance, appear to be unrelated (e.g. Chierchia 2004, Crain et al. 2005). We limit our discussion to two phenomena here. One phenomenon that features downward entailing operators is the licensing of negative polarity items (e.g. Kadmon & Landman 1993, Krifka 1995, Ladusaw 1979, Zwarts 1998). For example, sentences (5) and (6) illustrate that the negative polarity item *any* in English is licensed in the two downward entailing environments in (1) and (2), i.e. in the prepositional phrase headed by *before* and in the predicate phrase of the negative quantificational expression *nobody*.

- (5) Bill went to the cafe before *any* musician.
- (6) Nobody at this table likes *any* musician.

By contrast, negative polarity items are not tolerated in the corresponding non-downward entailing contexts, i.e. in the prepositional phrase headed by *after* or in the predicate phrase of the positive quantificational expression *everybody*. Examples (7) and (8) illustrate these ungrammatical linguistic structures, where the presence of *any* is not permitted.

- (7) Bill went to the café after **any* musician.
- (8) Everybody at this table likes **any* musician.

Downward entailing environments also govern the interpretation of disjunction (Crain 2008, 2012). When disjunction appears in the scope of a downward entailing operator, it licenses a ‘conjunctive’ entailment. The conjunctive entailment of disjunction under negation is one of the De Morgan’s laws of propositional logic: $\neg (A \vee B) \Rightarrow \neg A \wedge \neg B$ (see e.g. Partee, ter Meulen & Wall 1990). The conjunctive entailment of disjunction extends well beyond the case of negation, however, to downward entailing linguistic environments. For any downward entailing operator Δ , if a disjunctive phrase *A* or *B* appears in the scope of Δ , then the original disjunctive statement with Δ entails a conjoined statement in which Δ takes scope over both of the original disjuncts. The general schema for the conjunctive entailment of disjunction in downward entailing

linguistic environments is given in (9).

$$(9) \quad \Delta (A \text{ or } B) \Rightarrow \Delta A \text{ and } \Delta B$$

As a putative semantic universal, disjunction generates a conjunctive entailment in the scope of all downward-entailing operators. This linguistic universal encompasses a variety of linguistic expressions, as illustrated by the English examples in (10) and (11). In each case, the example entails a conjunctive statement in which the downward entailing operator in the original sentence combines with each of the disjuncts. Example (10) shows that disjunction yields a conjunctive entailment in the prepositional phrase headed by the preposition *before*. Example (11) shows that disjunction generates a conjunctive entailment in the predicate phrase of the negative quantificational expression *nobody*.

- (10) Bill went to the café before Amy or Betty.
 \Rightarrow Bill went to the café before Amy **and**
 Bill went to the café before Betty

- (11) Nobody at this table likes Amy or Betty.
 \Rightarrow nobody at this table likes Amy **and**
 nobody at this table likes Betty

It should be noted, again, that disjunction does not generate the conjunctive entailment in corresponding non-downward entailing structures, such as in the prepositional phrase headed by *after* or in the predicate phrase of the positive quantificational expression *everybody*. This is illustrated in examples (12) and (13).

- (12) Bill went to the café after Amy or Betty.
 $\ast \Rightarrow$ Bill went to the café after Amy **and**
 Bill went to the café after Betty

- (13) Everybody at this table likes Amy or Betty.
 $\ast \Rightarrow$ Everybody at this table likes Amy **and**
 Everybody at this table likes Betty

In short, downward entailing operators sometimes form minimal pairs with linguistic expressions that are not downward entailing. Whenever these minimal pairs are formed, they create 'asymmetries' in the interpretation of disjunction, and in the licensing of negative polarity items, such that only one member of the pair generates a conjunctive

entailment for disjunction and licenses negative polarity items. The other member of the pair has neither of these semantic properties.

One asymmetry in interpretation arises in sentences with the universal quantifier, English *every* or Mandarin *mei*. Before we discuss the phenomena, it will be helpful to clarify a few semantic terminologies with the universal quantifier. Following Heim (1982), sentences with quantifiers like *every* can be partitioned into a tripartite structure: a Quantifier, a Restrictor, and a Nuclear Scope. The Quantifier (e.g. *every*) combines with a noun or a noun phrase to form a grammatical unit (e.g. *every child* or *every child who ordered ice-cream*). The noun or noun phrase that the Quantifier combines with is called its Restrictor. Once the Quantifier combines with its Restrictor, the entire unit can be combined with a predicate phrase (e.g. *got a plate*). The predicate phrase is called the Nuclear Scope of the universal quantifier.

The restrictor and the nuclear scope of the universal quantifier *every* demonstrate different semantic properties with respect to downward entailment. Specifically, the restrictor is downward entailing, but not the nuclear scope. To verify this, notice that the restrictor (abbreviated ‘R’) licenses the inference from the set-referring term ‘ice-cream’ to the subset term ‘vanilla ice-cream’ in (14). However, the nuclear scope (abbreviated ‘NS’) does not license this inference, as (15) illustrates.

- (14) Every_R [child who ordered ice-cream] got a plate.
 \Rightarrow Every_R [child who ordered vanilla ice-cream] got a plate.
- (15) Every child who got a plate_{NS} [ordered ice-cream].
 \nRightarrow Every child who got a plate_{NS} [ordered vanilla ice-cream].

The universal quantifier conforms to other diagnostics of downward entailing operators. For example, the negative polarity item *any* is licensed in the restrictor, but not in the nuclear scope of *every*, as illustrated in (16). And when disjunction appears in the restrictor, it generates a conjunctive entailment, as illustrated in (17a). By contrast, when disjunction appears in the nuclear scope, which is not downward entailing, the sentence is true in all three circumstances that verify inclusive-*or*. Example (17b) is true if *every child who got a plate ordered ice-cream alone, or cake alone, or both ice-cream and cake*. We call this the ‘disjunctive’ truth conditions of disjunction in non-downward entailing linguistic contexts.¹

¹ A scalar implicature of exclusivity often reduces this range of truth conditions, by excluding circumstances in which both disjuncts are true (Horn 1972). This exclusionary implicature arises because the expression *or* forms a scale with *and* based on information strength, with *and* being more informative than *or* in non-downward entailing contexts. Language users are compelled by the Principle of Cooperation (Grice 1975) to use the strongest linguistic expression

- (16) a. Every_R [child who ordered **any** dessert] got a plate.
 b. Every child who got a plate_{NS} [ordered ***any** dessert].
- (17) a. Every_R [child who ordered ice-cream **or_{incl}** cake] got a plate.
 \Rightarrow every child who ordered ice-cream got a plate **and**
 every child who ordered cake got a plate
 b. Every child who got a plate_{NS} [ordered ice-cream **or_{incl}** cake].

So, disjunction is interpreted as inclusive-*or* in both downward entailing and non-downward entailing contexts, as indicated by '**or_{incl}**' in (17). However, the truth conditions that are assigned in non-downward entailing environments are broader in scope than those assigned to disjunction in downward entailing environments, since a downward entailing operator Δ limits the interpretation of disjunction to its conjunctive truth condition: $\Delta (A \text{ or } B) \Rightarrow \Delta A \text{ and } \Delta B$. We shall take advantage of this fact in our experimental studies.

Another hallmark of core linguistic properties is that they are manifested in typologically different languages. The fact that only one of the two arguments of the universal quantifier is downward entailing is therefore expected to extend across languages. As with English *every*, the restrictor of the Mandarin universal quantifier *mei* licenses inferences from expressions referring to sets of things to ones referring to subsets of those things, as example (18) shows. By contrast, the nuclear scope of *mei* does not license such inferences, as illustrated in example (19).

- (18) Mei-ge_R [dian-le bingjilin de xiaohai] dou dedao-le diezi.
 every-CL order-ASP ice-cream DE child DOU get-ASP plate
 'Every child who ordered ice-cream got a plate.'
 \Rightarrow Mei-ge_R [dian-le xiangcao bingjilin de xiaohai] dou dedao-le diezi.
 every-CL order-ASP vanilla ice-cream DE child DOU get-ASP plate
 'Every child who ordered vanilla ice-cream got a plate.'
- (19) Mei-ge dedao-le diezi de xiaohai dou_{NS} [dian-le bingjilin].
 every-CL get-ASP plate DE child DOU order-ASP ice-cream
 'Every child who got a plate ordered ice-cream.'
 $*\Rightarrow$ Mei-ge dedao-le diezi de xiaohai dou_{NS} [dian-le xiangcao bingjilin].
 every-CL get-ASP plate DE child DOU order-ASP vanilla ice-cream
 'Every child who got a plate ordered vanilla ice-cream.'

that is consistent with their state of knowledge. If a speaker uses the weaker statement *or*, hearers infer that the speaker was not in a position to use the stronger statement *and*, and the hearer infers the negation of the stronger statement, i.e. *not (A and B)*.

Let us apply the diagnostics of downward entailment to Mandarin *mei*. One of the diagnostics of downward entailment is the licensing of the conjunctive entailment of disjunction. The conjunctive entailment is not generated in non-downward entailing environments. This was illustrated earlier for English. The same differences in the truth conditions assigned to disjunction are manifested in Mandarin. Example (20) illustrates that the Mandarin disjunction operator *huozhe* generates a conjunctive entailment when it appears in the restrictor of the universal quantifier *mei*. However, when *huozhe* appears in the nuclear scope, as in (21), disjunction licenses the full range of truth conditions associated with inclusive-*or*.

- (20) Mei-ge_R[dian-le bingjilin huozhe dangao de xiaohai]
 every-CL order-ASP ice-cream or cake DE child
 dou dedao-le diezi.
 DOU get-ASP plate
 ‘Every child who ordered ice-cream or cake got a plate.’ = Conjunctive
- (21) Mei-ge dedao-le diezi de xiaohai dou_{NS}[dian-le bingjilin
 every-CL get-ASP plate DE child DOU order-ASP ice-cream
 huozhe dangao].
 or cake
 ‘Every child who got a plate ordered ice-cream or cake.’ = Disjunctive

The asymmetry in the truth conditions of disjunction in the restrictor versus the nuclear scope of the universal quantifier in English and in Mandarin is schematically represented in (22).

- (22) Every/Mei_R[...or/huozhe...] NS[...] = Conjunctive
 Every/Mei_R[...] NS[...] = Disjunctive

3. The acquisition of disjunction and universal quantification

All children eventually acquire the distinction between downward entailing and non-downward entailing contexts, and sort out which of the two arguments of the universal quantifier is which. There are two competing accounts of how knowledge of this kind is acquired, so that children converge on a grammar that is equivalent to that of adult speakers of the local language. According to one account, children extract linguistic knowledge from their input, using their domain-general abilities to form statistical generalizations based on distributional cues. This is the experience-dependent

account (e.g. Goldberg 2003, 2006, Tomasello 2000, 2003). In the alternative account, based on Universal Grammar, children come to the task of language acquisition equipped with innate knowledge of the core properties of human languages, and they draw upon this knowledge in converging on the target language (e.g. Crain 2008, 2012, Crain & Pietroski 2001, 2002, Crain & Thornton 1998). In this section, we point out several ways in which the acquisition of the interpretation of disjunction in sentences with the universal quantifier poses a challenge for the experience-dependent account. The observations invite us to take seriously the alternative account on which core linguistic properties are innately specified as part of Universal Grammar.

Sentences with disjunction and the universal quantifier pose a challenge for the experience-dependent account for several reasons. First of all, given the complexity of the linguistic structures under investigation, children's linguistic experience may offer them little decisive evidence for the requisite grammar formation. Indeed, an investigation of the primary linguistic data reveals that the majority of the input does not support the facts that children must learn. In a survey of 43,289 adult utterances in 3 Chinese corpora, i.e. the Beijing 2 corpus (Folders 2 and 3), the Zhou 1 and the Zhou 2 corpora in the CHILDES database (MacWhinney 2000), there was not a single instance of the requisite construction with *huozhe* in sentences with the universal quantifier *mei*. On the experience-based account, children may easily err when encountering the asymmetric interpretations of disjunction in the two arguments of *mei*, due to the rarity of the relevant input they receive. Moreover, it turns out that the disjunction word *huozhe* appears in great paucity in Mandarin Chinese. In particular, we found only 11 adult utterances with *huozhe* out of the total 43,289 adult utterances in the three Chinese corpora in the CHILDES database. Even among these few cases with *huozhe*, adult utterances generally contain *huozhe* in non-downward entailing contexts, which express alternative choices (e.g. *Jiang waiyu gei mama ting huozhe lai ge feiwen ba* 'Speak a foreign language to mum or give (me) a kiss') or mutual exclusivity (e.g. *Shuo hao huozhe buhao* 'Say good or not good'). This suggests that children's linguistic experience of disjunction is more consistent with the alternative, exclusive-or interpretation that dominates adults' daily usage of disjunction (cf. fn.2). If children construct their grammars solely on the basis of the primary linguistic input, they are more likely to erroneously conclude that disjunction is exclusive-or (French & Nelson 1985, Levy & Nelson 1994, Morris 2008). As a consequence, language learners would easily fail to capture the relationship between the property of downward entailment and the conjunctive entailment of disjunction, which holds only if disjunction is interpreted inclusively.

In addition, the experience-dependent account focuses on how children use statistical learning mechanisms to learn distributional patterns of morphological items. However, in learning the interpretation of disjunction in the two arguments of the universal

quantifier, what is learned is not a distributional property, i.e. the presence or absence of lexical items. Rather, what children learn is that the same disjunction word *huozhe* appears in both arguments of the universal quantifier, but is assigned with different truth conditions. Thus the differences are not in distribution, but in interpretation (Chierchia 2004). In this regard, even those most sophisticated statistical learning models (Lewis & Elman 2001, Reali & Christiansen 2005) might fail to detect distributional cues and to abstract requisite generalizations.

Exacerbating the problem of learnability is the fact that the universal quantifier (English *every*, Mandarin *mei*) stands apart from the majority of quantificational expressions. In other quantificational expressions, the two arguments of the quantifier do not differ in the direction of entailment relations. For instance, the negative quantifiers *nobody*, *none of the*, and *no* are all downward-entailing by either argument, as illustrated with *nobody* in (23). Other quantifiers, like *somebody*, are downward entailing in neither argument, as shown in (24). It is not a trivial task, then, to sort out those operators that are downward entailing in both arguments or in neither argument, from ones like English *every* and Mandarin *mei*, whose different arguments generate different truth conditions for disjunction. Moreover, if children form generalizations based on quantificational expressions like *nobody* or *somebody*, they might be expected to form the mistaken generalization that both arguments of the universal quantifier *every* are downward entailing (like *nobody*), and therefore license the conjunctive entailment of disjunction in both positions. Or, they might be expected to form the mistaken generalization that both arguments of the universal quantifier *every* are non-downward entailing (like *somebody*), and therefore fail to license the conjunctive entailment of disjunction.

- (23) a. Nobody who ordered ice-cream or cake got a plate.
 \Rightarrow nobody who ordered ice-cream got a plate **and**
 nobody who ordered cake got a plate
- b. Nobody who got a plate ordered ice-cream or cake.
 \Rightarrow nobody who got a plate ordered ice-cream **and**
 nobody who got a plate ordered cake
- (24) a. Somebody who ordered ice-cream or cake got a plate.
 $*\Rightarrow$ somebody who ordered ice-cream got a plate **and**
 somebody who ordered cake got a plate
- b. Somebody who got a plate ordered ice-cream or cake.
 $*\Rightarrow$ somebody who got a plate ordered ice-cream **and**
 somebody who got a plate ordered cake

These problems of learnability are circumvented if Universal Grammar guides the learner in grammar formation. On this approach children come armed with knowledge that disjunction is inclusive-*or*, and that the universal quantifier is downward entailing in the restrictor. On the UG-based approach, then, children are expected to demonstrate adult-like knowledge of the asymmetric truth conditions of disjunction in the two arguments of the universal quantifier, as soon as they figure out the relevant expressions for disjunction and the universal quantifier in the target language. From the UG perspective, children's knowledge is expected to be essentially adult-like from the earliest stages of language development. Young children's mastery of the interpretation of disjunction in sentences with the universal quantifier is therefore a good testing ground for alternative models of language acquisition. Before reporting the experimental findings, we review how previous cross-linguistic studies reveal children's knowledge of downward entailment, including children's knowledge of disjunction in sentences with the universal quantifier.

4. Downward entailment in child language: a cross-linguistic review

There is accumulative evidence that the semantic property of downward entailment emerges early in language development and across typologically different languages (see Crain 2008, 2012 for reviews). First of all, researchers have reported that young children across languages demonstrate adult-like knowledge that downward entailment unifies a cluster of linguistic phenomena. Specifically, children learning English (cf. Gualmini et al. 2003a, 2003b, O'Leary & Crain 1994) and Mandarin Chinese (Su et al. 2012) were found to demonstrate the knowledge that downward entailing contexts unify superficially unrelated linguistic phenomena, including the conjunctive entailment of disjunction and the licensing of negative polarity items. One representative study was conducted by Su et al. (2012), which investigated 3–5-year-old Mandarin-speaking children's interpretation of the disjunction word *huozhe* and the *wh*-word *shenme* in the predicate phrase of *meiyouren* 'nobody' (downward entailing) vs. the predicate phrase of *meigeren* 'everybody' (non-downward entailing). When *huozhe* appeared in the downward entailing predicate phrase of *meiyouren*, children interpreted sentences like *meiyou xiaochu juqi daishu huozhe xiaogou* 'no car lifted a kangaroo or a dog' as assigning a conjunctive entailment: *no car lifted a kangaroo and no car lifted a dog*. At the same time, when the Mandarin *wh*-word *shenme* appeared in the predicate phrase of *meiyouren*, children interpreted sentences like *meiyou xiongmiao chi shenme shuiguo* 'no panda ate any fruit' as statements. This indicates that children understood that the predicate phrase of *meiyouren*, a downward entailing context, generates the conjunctive entailment of *huozhe* and permits *shenme* to function as a negative polarity item. By

contrast, children allowed the disjunctive truth conditions of *huozhe* when it appeared in the non-downward entailing predicate phrase of *meigeren*, so they interpreted the sentence *mei-liang xiaochedou juqi-le daishu huozhe xiaogou* ‘every car lifted a kangaroo or a dog’ as meaning *every car lifted either a kangaroo or a dog (or both)*. Moreover, they knew that *shenme* maintained its question reading in this non-downward entailing context and thus provided answers to sentences like *mei-zhi xiongmao dou chi-le shenme shuiguo* ‘what kind of fruit did every panda eat?’ These findings were taken as evidence that child grammar incorporates core linguistic properties like downward entailment and therefore, without resorting to piecemeal learning, children master various linguistic phenomena associated with these properties (see Crain, Thornton & Khlentzos 2009).

Secondly, a series of cross-linguistic studies have demonstrated that young children generate the conjunctive entailment of disjunction in a number of downward entailing contexts, sometimes against apparently disparate interpretive patterns from the adult input. One set of supporting evidence comes from children’s adherence to de Morgan’s law in simple negative sentences across typologically different languages such as English (Crain, Gardner, Gualmini & Rabbin 2002, Gualmini & Crain 2002), Japanese (Goro & Akiba 2004) and Mandarin Chinese (Jing, Crain & Hsu 2005). Importantly, unlike this uniformity in child language, adults’ interpretation of disjunction in simple negative sentences is subject to a parametric setting of disjunction varied by the different scope relationships between disjunction and negation (Crain 2012, Crain & Thornton in press). In languages like English, negation takes scope over disjunction and de Morgan’s law is observed; whereas in languages like Japanese and Chinese, disjunction takes scope over negation and de Morgan’s law is not enforced. Interestingly, Japanese-speaking and Mandarin-speaking children were found to behave differently from adult speakers in their linguistic communities. The original study was conducted by Goro & Akiba (2004), using the Truth Value Judgment task (Crain & Thornton 1998). In a typical trial, a pig had eaten the carrot but not the green pepper. Japanese-speaking adults accepted the test sentence *the pig didn’t eat the carrot or the pepper* in this situation, by allowing disjunction to take scope over negation (i.e. they interpreted it as *it is either the carrot or the pepper that the pig didn’t eat*). However, distinct from adults’ interpretive pattern, 3–5-year-old children speaking Japanese were found to reject the test sentence, by saying ‘the pig did eat one of the vegetables’ or ‘it was only one of the vegetables that the pig didn’t eat’. This suggests that Japanese-speaking children, behaving like English-speaking adults and children (see Crain et al. 2002 for the English study), computed de Morgan’s law and generated the conjunctive entailment *the pig didn’t eat the carrot and he didn’t eat the pepper*. Similar findings were reported in Mandarin Chinese by Jing et al. (2005). Such mismatch between adult and child data in the local language is unexpected according to the experience-based approach (see Crain, Goro & Thornton 2006 for discussion).

Another set of cross-linguistic evidence stems from a recent study on children's interpretation of disjunction in sentences with a temporal conjunction such as English *before* and Mandarin *zai...zhiqian* (Notley et al. 2012). In adult language, the English disjunction operator *or* generates a conjunctive entailment in the scope of *before*, whereas the Mandarin operator *huozhe* can take scope over *zai...zhiqian*. The experimenters tested seventeen 3–5-year-old English-speaking children and twenty 4–5-year-old Mandarin-speaking children. The results showed that both English-speaking children and adults rejected the test sentence *the dog reached the finish line before the turtle or the bunny* in the situation in which the dog came second, before only one other participant. This indicated that they assigned the conjunctive entailment and paraphrased the test sentence as *the dog reached the finish line before the turtle and the dog reached the finish line before the bunny*. Resembling English-speaking children and adults, fourteen 4-year-old Mandarin-speaking children consistently rejected the corresponding Mandarin test sentence in the same context. By contrast, six 5-year-old Mandarin-speaking children as well as Mandarin-speaking adults allowed disjunction to take scope of '*zai...zhiqian*', so they accepted the test sentence and interpreted it as *the dog reached the finish line before the turtle or before the bunny*. Therefore, the data suggest that young children in both languages initially assign the conjunctive entailment to disjunction in the scope of temporal conjunctions, again regardless of the differences in adult preferences.

Furthermore, directly relevant to the current investigation are two English studies on children's understanding of *every...or...* sentences (Boster & Crain 1993, Gualmini et al. 2003a, 2003b). One study by Boster & Crain (1993) evaluated the truth conditions children assigned to *or* in the nuclear scope of *every*. Using the prediction mode of the Truth Value Judgment task (Chierchia, Crain, Guasti & Thornton 1998),² the experimenters tested children's understanding of test sentences like *Every ghostbuster will choose a cat or a pig*. The results showed that children did not treat the nuclear scope of *every* as downward entailing. This conclusion is based on the fact that children accepted test scenarios that supported the disjunctive truth conditions of *or* (e.g. each ghostbuster chose either a cat or a pig). Another study by Gualmini et al. (2003a, 2003b) investigated the truth conditions English-speaking children assigned to *or* in the restrictor of *every*. They addressed this question using the description mode of the Truth Value Judgment task (Crain & Thornton 1998). The experimenters presented children with sentences like

² This variant of the Truth Value Judgment task (the prediction mode) differs from standard usage in order to suspend any pragmatic implicatures that would otherwise arise in what might be called the description mode. In the prediction mode, the test sentences are presented to the subjects as predictions about what will happen in the remainder of the story, rather than as descriptions of events that have already taken place. This introduces uncertainty about how events will transpire, thereby suspending pragmatic implicatures based on information strength.

Every troll who ordered French fries or onion rings got some mustard in a context in which two trolls who ordered French fries got some mustard, two trolls who ordered onion rings got some ketchup and one troll who ordered a hamburger got nothing. The findings showed that children, like adults, consistently rejected the test sentences in this context. This indicates that children assigned a conjunctive entailment to *or* in the restrictor of *every*. Taken together, these two experiments provide supporting evidence that 3–5-year-old English-speaking children are aware of the asymmetric truth conditions of disjunction, early in the course of language development.

However, there are certain weaknesses in previous English studies on children's understanding of 'every...or...', particularly that certain aspects of the tasks make it hard to compare findings across the two experiments. For example, the child subjects were presented with test sentences containing relative clauses in the Gualmini et al. study (e.g. *Every troll who ordered French fries or onion rings got some mustard*), but the Boster & Crain study used much simpler test sentences without relative clauses (e.g. *Every ghostbuster will choose a cat or a pig*). In addition, children were evaluated with different modes of the Truth Value Judgment task (i.e. the prediction mode in the Boster & Crain study vs. the description mode in the Gualmini et al. study). These differences in the test sentences as well as in testing modes should be controlled if one wants to make a closer comparison of children's interpretation of disjunction in the two arguments of the universal quantifier.

More importantly, a linguistic property that is a candidate for innate specification should apply to all human languages. To our knowledge, the asymmetric truth conditions of disjunction in sentences with the universal quantifier have not been systematically investigated in languages other than English. Although Su et al. (2012) has tested children's interpretation of *huozhe* in the predicate phrase of *meigeren* (i.e., in the nuclear scope of the universal quantifier *mei*), Mandarin-speaking children's knowledge of the behaviours of disjunction in both the two arguments of the universal quantifier has not been evaluated in combination. If it is discovered that the same asymmetry appears at the initial stages of language acquisition among Mandarin-speaking children, as has been reported in previous English studies (Boster & Crain 1993, Gualmini et al. 2003a, 2003b), then this will provide further cross-linguistic evidence for the early emergence and universality of the core property of downward entailment in child language.

In the next section, we report our two experiments on Mandarin-speaking children's interpretation of *huozhe* in sentences with the universal quantifier *mei*. The first experiment includes test sentences with the universal quantifier *mei* in the pre-subject position, as in prior studies; and the second experiment, as a control experiment for Experiment 1, employs test sentences with *mei* in the object position, which has not been previously studied in any language. Moreover, in each experiment test sentences

were presented with similar levels of complexity, using the same testing mode, i.e. the description mode of the Truth Value Judgment task (Crain & Thornton 1998). Adopting a UG-based approach to language acquisition, the experimental hypothesis is that Mandarin-speaking children should demonstrate knowledge of the different truth conditions assigned to the disjunction word *huozhe* in the two arguments of the universal quantifier *mei*, as soon as they can be tested. In particular, they would be expected to behave adult-like in knowing that the restrictor of *mei* is downward entailing and, therefore, licenses a conjunctive entailment of disjunction. By contrast, they would be expected to understand that the nuclear scope of *mei* is non-downward entailing and, therefore, assigns a wider range of disjunctive truth conditions of disjunction.

5. Experiment 1

Experiment 1 is designed to investigate whether Mandarin-speaking children are aware of the different truth conditions associated with disjunction in the two arguments of pre-subject *mei*.

5.1 Subjects

The subjects consisted of thirty-one 3–5-year-old monolingual Mandarin-speaking children. The children ranged in age from 3;11–5;11, with a mean age of 4;10. The children were recruited from two kindergartens in Changsha, China: the Third Kindergarten affiliated with Local Government Departments and the Second Kindergarten affiliated with the Education Department of Kaifu District. In addition, 15 adult native Mandarin speakers served as a control group. These subjects were international Chinese students recruited at Macquarie University in Sydney, Australia.

5.2 Procedures

The experiment used the description mode of the Truth Value Judgment task (Crain & Thornton 1998). The Truth Value Judgment task is conducted by two experimenters. The first experimenter acts out stories in front of the child subject using props and toys. The second experimenter plays the role of a puppet (Kermit the frog) who watches the stories alongside the child. At the end of each story, the puppet produces a sentence which purports to accurately describe what happened in the story. The child's task is to judge whether or not the puppet's statement is 'right or wrong' (i.e. true or false). When a child indicates that the puppet's statement is wrong, the child is requested to explain to the puppet what really happened in the story. The explanation children produce is

used in the subsequent data analysis, to ensure that the child understood the story and produced a legitimate reason for rejecting the puppet's statement.

Child subjects were first introduced to the task as a group. Then they were tested individually in a quiet room, away from the classroom. Each child witnessed two warm-up stories. One was designed to elicit a 'Yes' answer and the other was designed to elicit a 'No' answer. If children answered both of the warm-up sentences correctly, and produced appropriate justifications for their 'No' response, they were invited to participate in the two main sessions of the experiment. Otherwise, children were eliminated from further testing. Four children said 'Yes' to both warm-up sentences and did not participate further. The 15 adult Mandarin-speaking subjects were tested individually by the main experimenter. However, they were only tested with one session combining all the test sentences (i.e. all the warm-up sentences, control sentences and filler sentences were deleted). The adult subjects were also invited to make a verbal judgment of the puppet's utterances. When they gave a negative reply, the subjects were requested to justify their answers.

5.3 Materials

The experiment used a within-subject design in which each child subject was tested using similar non-linguistic contexts for test sentences with both non-downward entailing contexts (i.e. *huozhe* appears in the nuclear scope of *mei*) and downward entailing contexts (i.e. *huozhe* appears in the restrictor of *mei*). For each experimental session of the two main sessions, the child subject was presented with four test stories, yielding eight test stories in total. In each session, the first two of the test sentences contained *huozhe* in the nuclear scope of *mei*, and the other two contained *huozhe* in the restrictor. The stories were designed to make the test sentences true, when *huozhe* appeared in the nuclear scope of *mei*, but false when it appeared in the restrictor of *mei*. This was accomplished by satisfying one of the disjunctive truth conditions, but not the truth condition corresponding to the conjunctive entailment of disjunction. To illustrate, here is one of the two stories in which *huozhe* appeared in the nuclear scope of pre-subject *mei*, a non-downward entailing context. The final outcome is illustrated in Figure 1.

This story is about five brave princesses who are on an adventure. There is a witch who steals treasure around the world, and the princesses want to steal some back. For protection, one princess brings a magic bird and each of the other four princesses brings a dog. The witch happens to go away and all five princesses find lots of treasure to take back: five jewels, five rings, one flower and one star. The princess who has the magic bird quickly decides to steal back the blue flower. Two of the princesses with dogs say, 'Jewels are more precious!' and each of them takes a jewel. The other two princesses with dogs say, 'Jewels look pretty, but rings are even better!' and each of these two princesses takes back a ring.



Figure 1: The Princess Story

As soon as the story concluded, the puppet produced a filler sentence *na-ge dai-zhe niao de gongzhu tou-le xingxing* 'The princess who carried the bird stole a star'. This sentence was false, and was expected to evoke a 'No' response from children. After the child subjects judged the truth or falsity of the filler sentence, the puppet produced the test sentence in (25).

- (25) Mei-ge dai-zhe gou de gongzhu dou tou-le baoshi huozhe jiezhi.
 every-CL carry-ASP dog DE princess DOU steal-ASP jewel or ring
 'Every princess who carried a dog stole a jewel or a ring.'

Notice that sentence (25) was true if children assigned disjunctive truth conditions to *huozhe*: every princess who carried a dog stole a jewel or a ring (or possibly both, but that did not eventuate in the story). However, if children failed to distinguish the two arguments of *mei*, they could reject sentence (25). There are at least two analyses of the test sentences that would result in negative judgments by children. One analysis that would result in a negative judgment would be if children understood *huozhe* 'or' to mean *he* 'and', as had been suggested in the literature (Paris 1973). If so, then children

would have taken sentence (25) to mean that every princess who carried a dog stole a jewel **and** a ring, so they would have rejected it on the grounds that each of the princesses with a dog took only one thing. A second reason why children might have rejected (25) is if they did not distinguish the two arguments of *mei*. This could happen, for example, if children analyzed both the restrictor and the nuclear scope of *mei* to be downward-entailing, thereby licensing a conjunctive entailment of disjunction in both positions. If so, children's interpretation of (25) would again require every princess with a dog to have stolen both a jewel and a ring, contrary to fact.

The remaining two test stories assessed whether or not children assigned the conjunctive entailment to *huozhe* when it appeared in the restrictor of pre-subject *mei*, a downward entailing context. The following represents one of the test trials and the final outcome is depicted in Figure 2.

Five aliens set off to buy vehicles so that they could tour the planet earth. The alien boss promises a gift to all aliens who purchase vehicles. Two aliens buy airplanes, two buy cars, and one alien buys a boat. The alien boss invites each of the aliens to choose from a pile of free gifts. Each of the two airplane-buyers chooses a star as their free gift. Then, the alien boss asks the aliens who bought cars if they also wanted stars, but they say 'No, we plan to drive to one of Earth's deserts. Do you have books about deserts?' So, each of these aliens receives a book about the desert. Finally, the alien who bought a boat chooses a suitcase as his prize, because he has to prepare for a journey to an ocean.

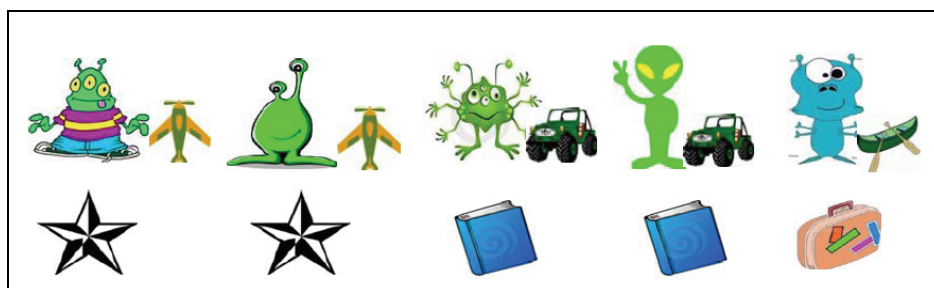


Figure 2: The Alien Story

At the end of the story, the puppet first produced a filler sentence *na-ge mai-le chuan de waixingren xuanze-le xiangzi* 'The alien who bought a boat chose a suitcase', which was true in this context. After the child made a judgment about the filler sentence, they were presented with the test sentence in (26).

- (26) Mei-ge mai-le feiji huozhe xiaoqiche de waixingren
 every-CL buy-ASP airplane or car DE alien
 dou xuanze-le shu.
 DOU choose-ASP book
 'Every alien who bought an airplane or a car chose a book.'

This test sentence received a different truth value depending on whether or not children assigned the conjunctive entailment to the Mandarin disjunction operator *huozhe*. If children knew that the restrictor of *mei* was downward entailing, they should generate the conjunctive entailment of disjunction and, consequently, they should reject the test sentence on the grounds that the two aliens who bought airplanes got a star. However, if children did not generate a conjunctive entailment, then they may accept (26), since the sentence could mean that *every alien who bought an airplane chose a book or every alien who bought a car chose a book*. This reading made the test sentence true because every alien who bought a car chose a book.³ The subjects may also accept (26) out of confusion or uncertainty, if they find the sentence too complicated to comprehend (Crain & Thornton 1998).

In addition to the four test sentences, there were two control sentences (one true and one false) in each session. The control sentences included the universal quantifier without disjunction, as in (27).

- (27) Mei-ge dai-zhe maozi de xiaohai dou na-le xingxing.
 every-CL wear-ASP hat DE child DOU take-ASP star
 'Every child who wore a hat took a star.'

These control trials were included to ensure that children could process relative clauses in sentences with the universal quantifier. As in test trials, each control sentence followed a filler sentence, e.g. *na-ge dai-zhe hua de xiaohai na-le xiaoqiu* 'The child who wore a flower took a ball'. In total, the subjects heard six such filler sentences in one session, which were designed to satisfy the felicitous situation of using the test sentences or control sentences with relative clauses. Moreover, the filler sentences were included to hold the child subjects' attention, and to balance the number of children's 'Yes' and 'No' responses. The experimental stimuli for Experiment 1 were presented in the 'Appendix'.

Children who failed to respond correctly to the control sentences or to the filler sentences were excluded from further analysis. Seven subjects were excluded from

³ An additional precaution was taken to remove a possible order effect. For half of the test sentences, the sentences were false in virtue of the first disjunct and, for the other half, the test sentences were false because of the second disjunct.

further data analysis because they wrongly accepted false control sentences and/or filler sentences. This left 20 children between the ages of 3;11 and 5;11, with a mean age of 4;11.

5.4 Results and discussion

This experiment examined whether children assigned different truth conditions to disjunction, when it appeared in the two arguments of pre-subject *mei*. If so, children would accept test sentences like (25) when *huozhe* appeared in the nuclear scope of *mei*. On the other hand, children were expected to reject test sentences like (26) when *huozhe* appeared in the restrictor of *mei*. The results confirmed these hypotheses. When *huozhe* was in the nuclear scope of *mei*, children accepted test sentences like (25) 95% of the time (76/80). By contrast, when *huozhe* was in the restrictor, the same children rejected test sentences like (26) 91% of the time (73/80). A Wilcoxon signed rank test revealed that children demonstrated significantly different response patterns across these two test conditions ($Z = 4.09$, $p < 0.0001$). Children also justified their negative judgments of test sentences like (26) for the right reasons. For example, in justifying their rejections of (26), children consistently pointed out that the two aliens who bought airplanes chose stars. The control group of 15 Mandarin-speaking adults correctly accepted the test sentences with disjunction in the nuclear scope of *mei* 97% of the time, but they rejected the test sentences with disjunction in the restrictor of *mei* 100% of the time, suggesting a distinct response pattern across these two conditions ($Z = 3.77$, $p < 0.0001$). A Mann-Whitney test further showed that children and adults behaved similarly when *huozhe* appeared in the two arguments of pre-subject *mei* (both $ps > 0.21$).

The results of our experiment corroborated the findings of previous studies on children's understanding of disjunction in sentences with the universal quantifier (see e.g. Boster & Crain 1993, Gualmini et al. 2003a, 2003b, Su et al. 2012). In addition to exhibiting adult-like knowledge of the interpretation of *huozhe* in the nuclear scope of *mei*, a non-downward entailing context (see also Su et al. 2012), children in our study also demonstrated their knowledge of the conjunctive entailment of *huozhe* in the restrictor of *mei*, a downward entailing context. Our findings indicate that knowledge of the different truth conditions of disjunction in the two arguments of the universal quantifier is evident not only in child English, but also in child Mandarin. Taken together, these data demonstrate children's mastery of the asymmetric interpretation of disjunction in sentences with the pre-subject universal quantifier, across typologically different languages.

At this point, we need to consider an alternative explanation for the present data, due to linguistic features specific to the Mandarin universal quantifier *mei*. In Mandarin

Chinese, the pre-subject universal quantifier *mei* typically co-occurs with the adverbial quantifier *dou*, which is generally acknowledged as a distributive universal quantifier, roughly equating to English *all* (Cheng 1995, Lee 1986, Lin 1998, Pan 2006, Portner 2002, Yeh 1993 among many others). In general, the presence of *dou* is obligatory when *mei* appears in the pre-subject position (Lee 1986, Yeh 1993), as shown in all our previous Mandarin examples with the co-occurrence of *mei* and *dou* (e.g. items (18)-(21) and (25)-(27)). It is worth noting that the universal quantifier *dou* is also downward entailing on its restrictor (i.e. the elements to its left). Moreover, there is empirical evidence that Mandarin-speaking children know that disjunction yields a conjunctive entailment, when it appears in the restrictor of *dou*. For example, in a study by Jing et al. (2005), 5-year-old children were tested with their understanding of sentences like (28), with *huozhe* appearing in the restrictor of *dou*. In a typical trial, one hat-wearing worker took a hammer, another hat-wearing worker took a pair of pliers and a wrench, the third hat-wearing worker took a pair of pliers, and the worker without a hat took a hammer. It was found that child subjects, like adults, rejected the puppet's description with sentence (28) 77% of the time by pointing out that the hatless worker also took a hammer. This suggests that children interpreted sentence (28) as assigning a conjunctive entailment, i.e. *workers who took a hammer are all wearing a hat and workers who took a pair of pliers are all wearing a hat*.

- (28) Na-le chuizi huozhe qianzi de gongren dou dai-zhe maozi.
 take-ASP hammer or pliers DE worker DOU wear-ASP hat
 ‘Workers who took a hammer or a pair of pliers are all wearing a hat.’

Proceeding with this, when *huozhe* appears in the restrictor of the pre-subject *mei*, it is possible that children may solely rely on their knowledge of *dou*, to render their judgment of the test sentences. To see this, when tested with sentence (26) *Mei-ge mai-le feiji huozhe xiaoqiche de waixingren dou xuanze-le shu* ‘Every alien who bought an airplane or a car chose a book’, children may offer their rejection simply based on their knowledge of sentence (29) with *dou* (i.e. without processing *mei*). Note sentence (29) also generated a conjunctive entailment *aliens who bought an airplane all chose a book and aliens who bought a car all chose a book*, which was also falsified in the situation in which the aliens who bought a car chose a book, but not the aliens who bought an airplane.

- (29) Mai-le feiji huozhe xiaoqiche de waixingren dou xuanze-le shu.
 buy-ASP airplane or car DE alien DOU choose-ASP book
 ‘Aliens who bought an airplane or a car all chose a book.’

To check the contribution of *mei* alone in children's judgments for sentences with the universal quantifier *mei*, in Experiment 2, we tested children using linguistic structures that only contained the universal quantifier *mei*, without the co-occurrence of *dou* (i.e. when *mei* appeared in the object position).

6. Experiment 2

In Experiment 2, we assess children's interpretation of disjunction, when the universal quantifier *mei* appears in a double object construction, i.e. when the *mei* noun phrase appears in the indirect object position and another noun phrase appears in the direct object position, as shown in examples (30) and (31). Note that when *mei* appears in the object position, the presence of *dou* is not obligatory.

- (30) Miqui gei-le mei-ge dian-le bingjilin huozhe dangao
Mickey give-ASP every-CL order-ASP ice-cream or cake
de xiaohai diezi.
DE child plate
'Mickey gave every child who ordered ice-cream or cake a plate.'
= Conjunctive
- (31) Miqui gei-le mei-ge dedao-le diezi de xiaohai bingjilin
Mickey give-ASP every-CL get-ASP plate DE child ice-cream
huozhe dangao.
or cake
'Mickey gave every child who got a plate ice-cream or cake.'
= Disjunctive

Notice that *huozhe* also licenses different truth conditions when it appears in the two arguments of post-verbal *mei*, as illustrated in examples (30) and (31). In sentence (30), the disjunctive phrase *bingjilin huozhe dangao* 'ice-cream or cake' resides in the restrictor of *mei*, as part of the relative clause that modifies the head noun *xiaohai* 'child'. Consequently, it generates the conjunctive entailment 'Mickey gave every child who ordered ice-cream a plate and he gave every child who ordered cake a plate'. By contrast, when *huozhe* appears in the nuclear scope of post-verbal *mei*, as in sentence (31), it allows the disjunctive truth conditions, meaning *Mickey gave every child who got a plate either ice-cream or cake or both*.

6.1 Subjects

Another group of thirty-four 4–5-year-old monolingual Mandarin-speaking children participated in this experiment. These subjects ranged in age from 4;01–5;08, with a mean age of 4;11. They were all recruited from the Blue Sky Art Kindergarten, Changsha. Moreover, 14 adult native Mandarin speakers in Macquarie University participated as a control group. None of these child or adult subjects participated in Experiment 1.

6.2 Procedures

Experiment 2 adopted the same methodology and testing procedures as Experiment 1. All children answered correctly to the warm-up sentences, and were introduced to the main testing session.

6.3 Materials

In the main session, the child subjects were presented with six test trials. Three test sentences contained *huozhe* in the nuclear scope of post-verbal *mei* and three contained *huozhe* in the restrictor of post-verbal *mei*. As in Experiment 1, the stories in Experiment 2 were designed to make the test sentences true in non-downward entailing contexts, but false in downward entailing contexts, using similar non-linguistic test scenarios. However, unlike Experiment 1, all the test sentences, control sentences and filler sentences in Experiment 2 were presented using double object construction. To illustrate, the following trial represents one of the three test trials, in which *huozhe* appeared in the nuclear scope of post-verbal *mei*, a non-downward entailing context.

Five dogs went to play games in a park where little hippo was the judge. Little hippo introduced a new riding game to the dogs, ‘Listen carefully, my dear dog friends! If you dare to ride on these new bicycles, you will be rewarded with free food!’ These dogs felt exhilarated at this challenging game, because none of them had ridden bicycles before. Four of the dogs successfully rode on bicycles. But one smallest dog failed in riding the bicycle and he rode on a wooden horse instead. At the end of the game, the little hippo rewarded two of the dogs that rode on bicycles with sausages and he gave cakes to the other two dogs that rode on bicycles. The smallest dog also got a bone for his participation in the game.

As soon as the story ended, the puppet first uttered a filler sentence *xiaohema jiang-gei nazhi qishang muma de xiaogou huluobo* ‘Hippo gave the dog that rode on a wooden horse a carrot’. It is obvious that the filler sentence was false, because the dog was rewarded with a bone, not a carrot. After the subject made a judgment of the filler sentence, the puppet described the final outcome by using test sentence (32).

- (32) Xiaohema jiang-gei mei-zhi qi-shang zixingche de xiaogou
Hippo reward-give every-CL ride-on bicycle DE dog
huotuichang huozhe dangao.
sausage or cake
‘Hippo gave every dog that rode on a bicycle a sausage or a cake.’

The subjects would be expected to accept sentence (32) with *huozhe* appearing in the nuclear scope of *mei*, if they understood it as a non-downward entailing context. If so, children should interpret sentence (32) as allowing the disjunctive truth conditions of *huozhe*, i.e. *Hippo gave every dog that rode on a bicycle either a sausage or a cake (or possibly both)*. The test scenario made this reading true. Nevertheless, they may reject sentence (32), if they incorrectly assigned a conjunctive entailment as in *Hippo gave every dog that rode on a bicycle a sausage and he gave every dog that rode on a bicycle a cake*.

The remaining three test trials assessed children’s interpretation of *huozhe* when it appeared in the restrictor of post-verbal *mei*, a downward entailing context. In a typical trial, the main experimenter acted out the following story:

Grandpa raised a lot of animals in his pasture, including a horse, two pigs, and two roosters. One day, all the animals ran away, when Grandpa went out to find some people to repair the broken fences. Fortunately, five children helped Grandpa to chase all these animals back. Grandpa was so happy that all the animals were brought back, so he rewarded each child with a small gift. The child who caught the horse got a lamp; two children who caught the roosters received two balls and two children who found the pigs received two books.

The subjects first judged the truth and falsity of a filler sentence *laoyeye jianggei nage zhuidao xiaoma de xiaohai taideng* ‘Grandpa gave the child that caught the horse a lamp’. The filler sentence was true in this context. Then, the puppet produced test sentence (33), with *huozhe* in the restrictor of post-verbal *mei*.⁴

⁴ To remove a possible order effect, among these three downward entailing test sentences, two were false because of the first disjuncts and one was false because of the second disjunct.

- (33) Laoyeye jiang-gei mei-ge zhuidao xiaozhu huozhe xiaoji de
 grandpa reward-give every-CL catch pig or rooster DE
 xiaohai xiaoqiu.
 child ball
 'Grandpa gave every child that caught a pig or a rooster a ball.'

The subjects would be expected to reject sentence (33), if they understood the restrictor of *mei* as downward entailing. This is because the appearance of *huozhe* in the restrictor of *mei* generates the conjunctive entailment: *Grandpa gave every child that caught a pig a ball and he gave every child that caught a rooster a ball*. The test scenario made the target sentence false because Grandpa gave every child that caught a pig a book, not a ball.

Besides the six test trials, there were two control trials. The two control sentences (one true and one false) were also presented by using double object construction, as illustrated in example (34). These control sentences were designed to verify that children had no problem with processing sentences with *mei* and the relative clause in double object construction.

- (34) Huaxianzi jiang-gei meizhi zhaidao hua de xiaoyang hudie.
 Flower Fairy reward-give every-CL pick flower DE sheep butterfly
 'Flower Fairy gave every sheep that picked a flower a butterfly.'

Each control sentence was also preceded by one filler sentence, e.g. *Huaxianzi jiang-gei na-zhi zhaidao lizi de xiaoyang qingcai* 'Flower fairy gave the sheep that picked the pear celery'. So, altogether the subjects were presented with eight filler sentences, each of which preceding one test sentence or control sentence. These filler sentences were either clearly true or clearly false. The filler sentences were designed to satisfy the felicitous situation of using the test sentences or control sentences with relative clauses. Moreover, they were included to verify that children could judge the truth and falsity of double object construction without disjunction.

Children who failed to respond correctly to the control sentences or to the filler sentences were excluded from further analysis. Under these criteria, the data of three children were eliminated from the final analysis, because they did not give correct answers to the control sentences or filler sentences. This left 31 children between the ages of 4;01 and 5;08, with a mean age of 4;11.

6.4 Results and discussion

The experimental hypothesis was that children would assign asymmetric truth conditions to disjunction in the two arguments of post-verbal *mei*, i.e. without relying on the contribution of the universal quantifier *dou*. If so, the subjects would be expected to accept test sentences like (32), when *huozhe* appeared in the nuclear scope of *mei*; moreover, they would be expected to reject test sentences like (33), when *huozhe* appeared in the restrictor of *mei*. The results were consistent with the experimental hypothesis. When *huozhe* was in the nuclear scope of *mei*, children accepted the test sentences 97% of the time (90/93). By contrast, when *huozhe* was in the restrictor of *mei*, the same children rejected the test sentences 91% of the time (85/93). A Wilcoxon signed ranks test showed that children demonstrated distinct response patterns across these two test conditions ($Z = 5.07$, $p < 0.0001$). Moreover, children justified their negative judgments for test sentences like (33) for the right reasons. For example, in justifying their rejection of (33), children consistently pointed out that Grandpa rewarded the children that caught pigs with books, rather than balls. The control group of 14 Mandarin-speaking adults correctly accepted the test sentences with *huozhe* in the nuclear scope of *mei* 98% of the time (41/42), and they rejected the test sentences with *huozhe* in the restrictor of *mei* 98% of the time (41/42). So, adults also provided significantly different responses across these two conditions ($Z = 3.56$, $p < 0.0001$). A Mann-Whitney test further revealed that children and adults behaved similarly when *huozhe* appeared in the two arguments of post-verbal *mei* (both $ps > 0.40$).

To conclude, consistent with Experiment 1, the data in Experiment 2 provide further evidence for children's mastery of the asymmetric interpretation of disjunction in the two arguments of the universal quantifier *mei*. Particularly, 4–5-year-old Mandarin-speaking children know that *huozhe* is associated with disjunctive truth conditions when it appears in the nuclear scope of post-verbal *mei*, a non-downward entailing context and they also know that *huozhe* yields a conjunctive entailment in the restrictor of post-verbal *mei*, a downward entailing context.

7. General discussion

This study assessed Mandarin-speaking children's semantic knowledge of the interpretation of the disjunction word *huozhe* in sentences with the universal quantifier *mei*. Experiment 1 examined whether children distinguished the different truth conditions related to *huozhe* in the restrictor versus the nuclear scope of pre-subject *mei*. Experiment 2 evaluated children's interpretation of *huozhe* when it appeared in the two arguments of post-verbal *mei*, a linguistic construction that had not been tested in previous child

studies. In both experiments, Mandarin-speaking children, like adults, understand that the universal quantifier *mei* is downward entailing in its restrictor and thus yields the conjunctive entailment of disjunction. By contrast, they also know that the universal quantifier *mei* is not downward entailing in the nuclear scope and thus allows the disjunctive truth conditions of disjunction.

Our data clearly demonstrate that children distinguish between the two arguments of the universal quantifier. It is important to note that the semantic property of downward entailment is the source of all of these asymmetries between the restrictor versus the nuclear scope of the universal quantifier *mei* in adult language. Therefore, children's adult-like interpretation of *huozhe* in sentences with the universal quantifier *mei* constitute compelling evidence that Mandarin-speaking children are aware of the semantic property of downward entailment at an early age. In sum, our experimental findings support the conclusions reached by previous psycholinguistic studies (see Crain 2008, 2012 for reviews), according to which the semantic notion of downward entailment (a) applies in different linguistic communities and (b) appears at an early stage of language development.

The research question is by what means children, in any language, figure out that the local language assigns different truth conditions to disjunction words in the restrictor of the universal quantifier, as compared to the same disjunction words in the nuclear scope of the universal quantifier. The answer we offer is directly relevant to the 'nature versus nurture' controversy. To explain the apparent gap between children's experience and their linguistic competence, we contend that children are innately endowed with knowledge of universal properties of grammar formation, such as downward entailment. The findings of experimental investigations on this topic (see Crain 2008, 2012 for reviews), including those of the present study, are difficult to reconcile with the experience-dependent account, which claims that children learn language based on the statistic regularities in the primary linguistic input. The UG-based account seems much more plausible.

Appendix

Puppet's Statements in Child Experiment 1 (Translated from Mandarin Chinese)

Trial Type	Sentence Type	Puppet's Statements in Session 1	Puppet's Statements in Session 2
Warm-up	Warm-up	The dog found the ball. (True)	Donald Duck found Mickey Mouse. (True)
	Warm-up	The dog found the horn. (False)	Mickey Mouse found the little lion. (False)
Test trial	Filler	The princess who carried a bird stole a flower. (False)	The horse that jumped over the flower received a shell. (False)
	Test	Every princess who carried a dog stole a diamond or a ring. (True)	Every horse that jumped over the fence received a star or a jewel. (True)
Control trial	Filler	The lady that rode a little horse received a ball. (True)	The child that wore a pair of glasses took a ball. (True)
	Control	Every lady that rode a big horse received a star. (False)	Every child that wore a hat took a jewel. (False)
Test trial	Filler	The turtle that drove an airplane took a teddy bear. (False)	The princess who held a sea star bought a rabbit. (False)
	Test	Every turtle that drove a boat took a rooster or a monkey. (True)	Every princess who held a shell bought a frog or a dog. (True)
Test trial	Filler	The child who lifted the bird took a ball. (True)	The dog that picked the leaf got a star. (True)
	Test	Every child who lifted a monkey or a kangaroo took a jewel. (False)	Every dog that picked the red flower or the white flower got a butterfly. (False)
Control trial	Filler	The robber who wore a mask stole an eggplant. (False)	The car that carried a flower jumped on a chocolate tree. (False)
	Control	Every robber who wore a hat stole a strawberry. (True)	Every car that carried a ball jumped on a box. (True)
Test trial	Filler	The fish who ate a pepper ordered a banana. (True)	The alien who bought a boat chose a suitcase. (True)
	Test	Every fish who ate a chip or a peanut ordered a cup of tea. (False)	Every alien who bought an airplane or a car chose a book. (False)

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漢語兒童析取連詞和全稱量化的習得

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向下蘊涵語境決定析取連詞的語義解讀。當析取連詞出現在全稱量詞的限定域（向下蘊涵語境）或核心轄域（非向下蘊涵語境）中時，其解讀在各語言中均存在著普遍非對稱性。本文旨在探索漢語兒童在包含全稱量詞“每”的句子中，對析取連詞“或者”的解讀。研究發現，當“或者”出現在“每”的限定域中時，兒童的解讀符合析取連詞在向下蘊涵語境中所指派的合取蘊涵關係；而當“或者”出現在“每”的核心轄域中時，兒童的解讀符合析取連詞在非向下蘊涵語境中所指派的析取真值條件。本文進一步證實：向下蘊涵是一種存在於各種語言並且出現於兒童語言發展早期階段的“核心”語義屬性。

關鍵詞：向下蘊涵，析取連詞，全稱量化，語言習得，漢語