Domain restriction in child Mandarin: implications for quantifier spreading

Alan Hezao Ke

University of Michigan, Ann Arbor

hezaoke@umich.edu

Liqun Gao

Beijing Language and Culture University

gaolq@blcu.edu.cn

Abstract This study explores children's competence with quantifier domain restriction. We present results from two experiments in which participants evaluated two possible candidates for the domain selection associated with the distributive operator *dou* 'all' in Chinese. In the first experiment, we investigated whether children and adults are capable of selecting an appropriate domain when two candidate noun phrases (NPs) both appear inside *dou*'s quantification scope; i.e. both of the NPs c-command *dou*. In the second experiment, we tested subjects' selection of domain when *dou* appears between two candidate NPs, one within its scope and the other outside its scope. Our results indicate that 4- to 5-year-old children are capable of basic distributive computation associated with *dou*, but because they are more flexible in domain restriction than adults are, they may choose a different candidate as the domain of *dou*, resulting in non-adult interpretations of distributive computation in certain cases. These results have important implications for the current debate on the acquisition of universal quantifiers, *quantifier spreading* specifically, supporting the view that children's non-adult quantifier interpretation may arise from flexibility in domain selection rather than incompetence with distributive computation.

Keywords: distributive computation, *dou*-quantification, universal quantifier, domain restriction, language acquisition, Mandarin Chinese

Domain restriction in child Mandarin: implications for quantifier spreading

1 Introduction

1.1 Problems with universal quantification: what do symmetrical responses tell us?

Studies on the acquisition of quantifiers have uncovered a puzzling phenomenon among 3- to 10-year-old children. For example, Philip (1995) presented adults and children with a picture depicting 3 pigs and 4 apples, where each pig is eating one apple, leaving one apple uneaten (in the picture there was also a dog eating a bone). When presented with this picture, almost all adults will say **Error! Reference source not found.**) is a correct description of the scenario, because for adults the domain[1] of the universal quantifier *every* includes only the subject NP *pig*, not the object NP *apple*.

(1) Every pig is eating an apple.

On the other hand, children between 4 and 5 years old judged (1) to be false. The children, pointing to the extra apple (which we will call the *extra object*), typically provided the following reason to justify their judgment: there is no pig eating the extra apple. In other words, they seemed to require an exhaustive pairing between the pigs and the apples.

What leads to such a non-adult response? Philip (1995) proposed that the exhaustive pairing is a

[1] We call the syntactic object that the quantifier quantifies over the domain of this quantifier.

result of a symmetrical interpretation as shown in (2),[2] where the quantifier *every* "spreads" its domain to the object NP. The exhaustive reading is thus also called *quantifier spreading*.

(2) Every pig is eating an apple, and every apple is being eaten by a pig.

The quantifier spreading problem leads to a question that has interested many researchers: Are 4- to 5-year-old (and even older) children competent with universal quantification/distributive computation? According to Philip (1995), quantifier spreading is driven by a non-adult semantic representation of the universal quantifier. Philip argues that children may misunderstand *every* to be a universal quantifier that takes events, rather than individual objects, as its domain, as shown in (3). In other words, for adults, *every* quantifies over only the NP it syntactically merges to, taking that NP and only that NP as its domain, but for children, *every* may take the whole event as its domain.

(3) All minimal events in which either a pig or an apple (or both) is a participant are events in which a pig is eating an apple.

Researchers have raised several concerns regarding Philip's (1995) account. First, the dual-status of

[2] Philip (1995?) formalized this interpretation in terms of event semantics. We present a plain English analysis for the sake of simplicity.

every, that is, *every* can both quantify over events or sets of individuals, causes a learnability problem. Since children still provide adult-like answers in addition to the symmetrical responses, we must assume that children can interpret *every* either as a determiner quantifier or an adverbial event quantifier such as *always*. Therefore, adults' productions will always be consistent with one of the assumed interpretations that children assign, and so children will need to unlearn the event-quantification interpretation (see 2, 3) in the absence of negative evidence (Crain et al. 1996; Philip 2011). [3] We will return to the acquisition issue later in the General Discussion. Second, as pointed out by Crain et al. (1996), an important source of children's symmetrical responses is the flawed experimental design, i.e. the presence of an extra object, e.g. the fourth apple in (1), in the pictures used in the experiments, which may be a hint that this extra object was relevant to the truth value judgment of the test sentence. In other words, a child who takes the extra object as pragmatically relevant for the judgment of the truth value of (1) will conclude that the correct, expected answer is "No." This child may be attracted by the extra object, reasoning that (1) should be judged by taking the extra, uneaten apple into consideration. In this case, the child will simply choose the pragmatically felicitous response and violate a syntactic principle of quantifier domain restriction that is in conflict with an overriding pragmatic principle.

Crain et al. (1996) argued that Philip's simple 'yes/no' task suffers from the experimental design flaw because no alternative to assertions like (1) are provided. If the choice between (4a, b) were provided

[3] A syntactic deficiency account such as Roeper et al.'s (2011) quantifier floating approach suffer from the same critism with the semantic approach: acquisition problem and the extra object issue.

instead, Crain et al. (1996) predicted, children would not be attracted by the extra objects since their existence is reasonably justified by the *condition of plausible dissent* (p. 116; see also Freeman et al. 1982). In a series of experiments, Crain et al. (1996) argued that such a design flaw can be ameliorated by introducing a choice between (4a, b). Experiments conducted by Crain et al. (1996), validate this proposal, confirming that children do not have problems with universal quantification and distributive computation. However, even though it is true that under certain conditions children's symmetrical responses can be eliminated, we still lack a principled explanation for why, under the single extra object condition specifically, such a high percentage of non-adult symmetrical responses are observed (Philip 2004; Minai et al. 2012).

(4) a. Every pig is eating an apple.

b. Some pigs, but not all, are eating an apple, and the rest are eating something else.

A number of other explanations for children's symmetrical responses can be categorized as pure syntactic/semantic deficiency, or syntax-to-semantics mapping deficiency approaches (Roeper & de Villiers 1991; Roeper et al. 2005; Brooks & Sekerina 2006; Roeper et al. 2011), in keeping with Philip (1995), assuming children's symmetrical responses are due to their non-adult knowledge status regarding universal quantification or distributive computation. Still others advocate for pure pragmatic or cognitive deficiency approaches (Gouro et al. 2001; Gualmini et al. 2003a; Rakhlin 2007; Minai et al. 2012), an approach shared by Crain et al. (1996), suggesting that children do not have problems with universal quantification, but rather the observed non-adult behavior in universal quantification is caused by pragmatic factors inadvertently induced by the experimental design. Another popular string of proposals are combinatory approaches, the weak quantification hypothesis specifically, resorting to both syntactic/semantic and pragmatic factors (Drozd 2001; Geurts 2003; Drozd 2004; Drozd & van Loosbroek 2006; Drozd et al. submitted), i.e. children's weak quantifier representation of *every* allows pragmatic factors to have an important influence on the interpretation of *every*. The three categories of approaches and their representative studies are listed in (5).

(5) a. **Syntactic/semantic, syntax-to-semantics mapping deficiency approaches**: Roeper & de Villiers 1991; Philip 1995; Brooks & Sekerina 2006

b. **Pragmatic or cognitive deficiency approaches (no linguistic deficiency)**: Crain et al. 1996; Gouro et al. 2001; Gualmini et al. 2003a; Rakhlin 2007; Minai et al. 2012

c. **Combinatory approaches**: Drozd 2001; Geurts 2003; Drozd 2004; Drozd & van Loosbroek 2006; Drozd et al. submitted

One locus of the debate between the proposals is whether children have adult-like syntactic and semantic knowledge of universal quantification, and whether pragmatic or cognitive factors affect children's interpretation of quantification. Three pieces of evidence from previous studies are worth a comprehensive discussion in order to adequately evaluate these three types of proposals.

(i) Children are competent with universal quantification and distributive computation. Adult-like responses have been obtained from children on the interpretation of universally quantified sentences with *all*, *every* and *each* in English (Brooks & Braine 1996; Crain et al. 1996; Meroni et al. 2000; Gualmini et al. 2003a; b; Minai 2006; Notley et al. 2008) and corresponding quantifiers Chinese and Portuguese (Brooks et al. 2001). This supports the pure pragmatic or a cognitive deficiency approaches.

(ii) Studies show that children do not have problems with weak quantifiers such as *one*, *two*, *many*, *few*, but have difficulties with strong quantifiers such as *all* and *every* (Geurts 2003 and the citations therein). The combinatory approaches hypothesize that children may interpret strong quantifiers in the same way as weak quantifiers, and because strong quantifiers are more complex than weak quantifiers, it is necessary for children to process strong quantifiers as weak ones (Drozd et al. submitted; see Haider et al. 2017 and Geurts & van Tiel 2015 for recent developments along these lines). There are two reasons to suppose that strong quantifiers are more complex than weak ones.

First, strong quantifiers obligatorily convey an existential presupposition that the 'denotations' of their domains already exist. For instance, (6) presupposes the existence of a set of billionaires.

(6) Every billionaire bought two islands.

The second reason concerns the essential distributive relation between the domain (the "distributive key") of *every*/*each* and the rest of the sentence (the "distributive share"). Again, take (6) above: the predicate 'bought two islands' is an attribute which is distributed to each member of the quantificational domain (each of the relevant billionaires). In the distributive interpretation, there is a one-to-two corresponding relation between the set of billionaires and the set of islands (cf. Geurts & van Tiel 2015).

However, evidence for the weak-quantification hypothesis is quite mixed. Children seem not to have difficulties with the above two aspects of universal quantification. On the one hand, children actually have knowledge of the existential presupposition of the strong quantifier *every*'s domain, and they distinguish the NP in the domain of *every* from the NP in the nuclear scope (Gualmini et al. 2003b; Yatsushiro 2008; Rakhlin 2009). On the other hand, mixed results have been obtained regarding children's processing of the distributive relation between the domain and the predicate. Children are found to interpret 'every' and 'each' primarily as distributive, though the collective reading is still more frequent in children than in adults. (Brooks & Braine 1996; Brooks et al. 2001). Even sentences with weak quantifiers such as cardinals (7a) are in fact primarily interpreted as distributive (7b), although the collective reading is also available (Drozd et al. submitted, see also Hollebrandse & Smits 2005; Smits et al. 2008).

(7) a. Three cowboys are pulling two horses.

b. Each of the three cowboys is pulling two horses.

(iii) Various salience effects suggest that the selection of the domain for strong quantifiers is affected by various factors. Such salience effects are reported extensively, and we consider a review of these salience effects crucial to understanding the nature of quantifier spreading.

(a) Increasing the salience of the target quantifier domain (the NP that *every* merges to) in adult grammar, e.g. by bringing the domain of quantifiers to children's attention or introducing it as a discourse topic before the presentation of the test sentence, reduces the proportion of symmetrical responses significantly (Crain et al. 1996; Hollebrandse 2004; Drozd & van Loosbroek 2006).[4] For example, Freeman, Sinha, & Stedmon (1982) showed that children's responses may be affected by certain variation in presentation of experimental stimuli. (see also Drozd 2001). Freeman, Sinha, & Stedmon found that, if a story is about cows, then children paid more attention to cows, and 89% of the participants required an exhaustive interpretation on cows; but when the story was about cowsheds that were burning down, 77% of the same children adopted a strategy that requires an exhaustive interpretation of cowsheds in the story context. In addition, Hollebrandse (2004) clearly showed that when the subject NP (the domain of the quantifier) is also the discourse topic, the symmetrical responses elicited by pictures with an extra object decreases significantly.

In Crain et al. (1996), with the condition of plausible dissent satisfied in a scenario such as (4), a contrast is actually formed between a subset of the pigs and the rest of the pigs: they are eating different food. This contrast may cause the pigs, as the domain of the quantifier, to stand out in the discourse (cf. Brooks & Sekerina 2006). In this case, it is very possible that children's attention to the test sentence is shifted from the extra object to the subject NP, which explains why Crain et al. (1996) observed that symmetrical responses were almost eliminated. (The impact of the contrast even overshadows the sa-

[4] See Arnold (1999), Cowles (2006), Cowles et al. (2007) for psycholinguistic evidence for the salience status of topic compared to non-topic.

lience of the extra object in Meroni et al. 2000).

(b) Increasing the salience of the extra object will increase the amount of symmetrical responses. For example, a very high percentage (95%) of symmetrical responses were obtained in Crain et al.'s (1996) Part B, Experiment 4, when the extra objects were made salient.

(c) Decreasing the salience of the extra object reduces symmetrical responses. Kiss and Zétényi (2017) replicated quantifier spreading in Hungarian 5-year-olds with iconic drawings typical of previous studies on quantifier spreading. However, when replacing these iconic drawings with photos taken in a natural environment that are rich in accidental details, the occurrence of quantifier spreading was radically reduced. Kiss and Zétényi (2017) argued that in traditional pictures with one extra object, the extra object is taken as relevant to the judgment task, given Csibra and Gergely's (2009) Natural Pedagogy theory (based on Sperber and Wilson's (1986; 1995) Relevance Theory). An important effect alongside the distracting and noisy background in the pictures is that the extra object becomes more trivial and less relevant. Therefore, it could be that the extra objects are less salient in the photos than in the iconic drawings (cf. Gordon 1998), which might have led to a reduction of the symmetrical responses.

Similarly, Gouro et al. (2001) decreased the salience of the extra object with two design features. In one condition, Gouro et al. used different types of objects so the extra object is no longer "uniquely exceptional". In another condition, Gouro et al. included a context before the presentation of the traditional single extra object pictures, and in the context they made the extra object less relevant to the truth value of the test sentence. For example, while the test sentence is about cats riding ponies, the context given before the presentation of the test sentence is not about riding but about whether the cats should get close to the ponies. In both cases, the percentage of symmetrical responses dropped significantly. Freeman (1985) showed that when the extra object is paired by an irrelevant, unmentioned agent, symmetric responses are significantly reduced, suggesting that the presence of this unmentioned agent lessens the salience of the extra object for the children (Drozd 2001).

Lastly, increasing the number of the extra objects also decreases the salience of each of the extra objects and thus prohibits quantifier spreading (Sugisaki & Isobe 2001; Minai et al. 2012). Sugisaki & Isobe (2001) included 6-7 extra objects in the testing pictures, and Minai et al. (2012) used 3 extra objects. Both studies found that with multiple extra objects, the percentage of symmetric responses decreases significantly. Further, Minai et al. (2012) found evidence that when pictures depicting multiple extra objects were presented before pictures with a single extra object, the percentage of symmetrical responses was higher than when the single-extra-object-pictures were presented first. Minai et al.'s eye movement data also show that the mean proportion of eye fixation on the extra object(s) in the single-extra-object condition is much higher than that in the multiple-extra-object condition. Minai et al. (2012) thus suggested that with multiple extra objects, the extra objects lose their "uniqueness" status as in the single extra object condition, decreasing the salience of the extra object.

The multiple extra objects design may have contributed to the decrease in the symmetrical response observed in Crain et al. (1996). The scenarios in Crain et al. (1996) typically involve more extra objects than those in Philip (1995). For instance, there are 3 extra objects in Experiment 4, and 2 extra objects (in addition to 5 other extra objects not mentioned in the test sentences) in Experiments 2, 3 and 5.

Of course, a formal theory of salience (in the visual domain as well as the linguistic domain) is needed in order to make a decisive evaluation. However, the evidence available seems to converge in that the salience of the extra object and the domain of the quantifier has an important impact on the percentage of symmetrical responses obtained in previous studies.

1.2 Evaluate the proposals

Now we are at the point to evaluate the various explanations of symmetrical responses in (5) with the reviewed findings in the previous studies. Experimental results suggest that children have adult-like competence in universal quantification and distributive computation, which favors the pragmatic approaches (5b) and disfavors competence deficiency approaches including the syntactic/semantic competence deficiency approaches (5a) and the combinatory approaches (5c). In addition, the competence deficiency approaches either have learnability issues (Crain et al. 1996; Gualmini et al. 2003a; b) or cannot be fully justified by their mixed results. Lastly, various salience effects on children's domain selection, on the other hand, cue us that children's domain restriction must be different from adults', at least in certain aspects. The consistently observed salience effects suggest that a slight difference in domain selection may have caused children's interpretation of universal quantification to be affected by the salient status of the domain or that of the extra objects in the experimental setting. The combinatory approaches make an explicit prediction regarding the salience effects, in contrast to the pragmatic approaches, which cannot account for the salience effects in a principled way without a significant modification. Therefore, it seems the current results can hardly be fit into the predictions of any of the above approaches.

In this paper, we will argue that, following the pragmatic approaches, children do have knowledge of universal quantification or distributive computation. We hypothesize that the salience effects in domain selection hinges on children's flexibility in domain restriction, that is, they are more flexible than adults in restricting the quantifying domain only to NPs inside its scope. On this hypothesis, the question immediately arises: why children should be more flexible with domain restriction. In the following section, we will present two experiments investigating children's selection of quantifier domain when there are two candidates available, and argue that Yang's (2000a; 2002) model of language acquisition and language change provides a good explanation of the flexibility of domain restriction. Specifically, we will address two questions regarding domain restriction in universal quantification in Chinese among children and adults:

(8) a. Are children competent with universal quantification?

b. Are children's domain restrictions different from adults' in a way that can account for the various salience effects in children's interpretation of universal quantification or distributive computation?

1.3 Dou-quantification

In section 1.2, we hypothesized that a promising explanation of children's symmetrical responses is that children's domain restriction may be slightly different from adults' regarding universal quantification.

If this explanation is on the right track, we do not need to assume that children are different from adults with regard to their syntactic and semantic knowledge of universal quantifiers. Children do not misunderstand *every* as an event quantifier (Philip 1995), or an adverbial quantifier (Roeper et al. 2005; Roeper et al. 2011), or a weak quantifier (Drozd 2001; Geurts 2003). As Grimshaw & Rosen (1990) and Kang (2001) had noticed, children may have knowledge of certain linguistics restrictions, yet disobey them anyway. Our hypothesis is that children may not have a solid belief on certain restriction, specifically the domain restriction of *every* (*every* must take the NP it merges with as its domain). In other words, although children know, perhaps in a probabilistic sense, that only the NP with which *every* merges is its domain, since the probability of the relevant restrictions are not that high, the restrictions can be violated, especially when the violation results in an interpretation that is more consistent with the context. This explains why children can extend the scope of *every* to a salient NP outside of its typical scope. We will argue that the language acquisition procedure is responsible for this flexibility of domain restriction in the General Discussion section. For adults, on the other hand, the probability of the relevant restrictions is raised given more positive input, and consequently the restrictions will be less possible to be violated. This explains why adults make much less quantification domain restriction errors than children, but meanwhile such errors still exist in cases where the context strongly encourages a violation of the restrictions. A prominent example of such errors in adults can be found in Minai et al.'s (2012) study, where they found that the adult subjects had about 30-40% of symmetric responses in the single-object condition (where single-object pictures were presented before the test sentence) when this condition is presented first, suggesting that even the adults were affected by the salient status of the extra object.

In this paper, we use data from Chinese to investigate whether children behave differently from adults in domain restriction. We investigate 4- to 5-year-old children's acquisition of the distributive operator *dou* (roughly corresponding to *all* in English) in Mandarin Chinese (*Chinese* hereafter).

Dou is usually considered a distributive operator or a universal quantifier (Lee 1986; Chiu 1993; Cheng 1995; Lin 1996; Zhang 1997; Lin 1998; Wu 1999; Chen 2008). The syntax and semantics of *dou* elicits much debate, but most authors agree that *dou* is directly or indirectly associated with universal force/exhaustivity or distributivity (Giannakidou & Cheng 2006; Xiang 2008; Cheng 2009; Tsai 2015; Liu 2016; Xiang 2016b; a; Liu 2017; In press). Furthermore, since our experimental materials are concerned about only *dou*'s universal quantification/distributivity use, we adopt the idea from Lin (1996; 1998) that *dou* is a distributive operator that carries universal force. In contrast to Lin (1996, 1998), we do not make a distinction between a universal quantifier and a distributive operator since the distinction is irrelevant to our discussion.

As a generalized distributive operator, *dou* introduces a tripartite structure, including the restrictor/domain,[5] the operator and the nuclear scope (Heim 1982; Lin 1998). For example, *dou* in sentence (9) derives a tripartite structure as shown in (10). *Dou* distributes the property represented by the VP over every member of the domain, where "every member" indicates universal force. In order to be the

[5] We do not distinguish *distributive operator* from *universal quantifier*, or *domain* from *restrictor*.

domain of *dou*, an NP must c-command *dou* (Chiu 1993; Zhang 1997; Lin 1998).[6] In the case of (9), supposing that there are three tortoises in the context, then each of the tortoises should have the property of planting an orchid, because only the subject NP *wugui* 'tortoise' c-commands *dou* and thus can be *dou*'s domain.

(9) Wugui dou [$_{VP}$ zhong-le lanhua].
tortoise all plant-ASP orchid
'The tortoises all planted (an) orchid(s).'

(10) tortoise dou plant orchid
[domain] D-operator [nuclear scope/property]

It can become more complicated when there are two eligible candidates for the domain within the scope of *dou*[7]. For instance, (11), which is a test sentence for Experiment 1 (Section 2.2), is a case where both *wugui* 'tortoise' and *laoying* 'eagle' c-command *dou* and thus are both in *dou*'s scope (see below a

[6] We do not consider the non-distributivity use of *dou* in this study, where *dou* is associated with an syntactic object that does not necessarily c-command *dou*.

[7] *Scope* (of *dou*) here is different from *nuclear scope* in that the former refers to all the syntactic objects c-commanding *dou* in a structure. The restrictor of *dou* is selected from the scope of *dou*. Therefore, our definition of scope is different from Tsai's (2014; 2015), who defines the syntactic objects that are c-commanded by *dou* as *dou*'s scope. In fact, Lin (1998) also assumed that *dou* binds a variable inside *dou*'s c-commanding scope, however, in order to agree with *dou*, the head of the variable must move to a position that c-commands *dou*.

discussion of the dual-status of the preposition in Chinese). It is important to know in this case, which NP will be selected as the domain of *dou*.

(11) A typical test sentence of Experiment 1

Wugui [$_{PP/NP}$ zai laoying pangbian] *dou* zhong-le lanhua.

tortoise at eagle side *dou* plant-ASP orchid

'The tortoise(s) at the eagle(s) side all plant an orchid.'

(12) a. If selecting *wugui* 'tortoise' as the domain:

'All of the tortoises planted an orchid at the sides of the eagle.'

b. If selecting *laoying* 'eagle' as the domain:

'Besides all of the eagles there is an orchid which is planted by the pandas.'

Cheng (1995) argued that in adult grammar, (11) is ambiguous, depending on which NP is quantified by *dou*. This is because of the dual status of the preposition in Chinese. *Zai* 'at' as a preposition can either project or not project. When it projects as P and then PP, the NP inside this PP does not c-command *dou*, and thus is not in *dou*'s scope and cannot be *dou*'s domain. This syntactic possibility leads to meaning (12a) where only the subject NP *wugui* 'tortoise' is quantified by *dou*. However, if the preposition does not project and is vacuous, the NP c-commands *dou* and thus can be its domain. Based on the Principle of Economy of Derivation (Chomsky 1991), Cheng (1995) suggests that *dou* should quantify over only the closest NP inside its scope ("making the shortest move" in Cheng's terms). That is, *dou* could distribute over only the NP *laoying* "eagle" when the NP inside PP projects, resulting in meaning (12b).

Children and adults' selection of domain from two candidates will be investigated further in the second experiment (Section 2.3) using test sentences such as (13), which includes two NPs: one NP, *xiaodongwu-men* 'animals' is inside *dou*'s scope, and the other, *dianshi, chuang he bingxiang* 'TV, bed and fridge' is outside *dou*'s scope. If the former NP is quantified by *dou*, meaning (14a) is obtained; if the latter NP is quantified, (14b).

(13) A typical test sentence of Experiment 2

Xiaodongwu-men	*dou*	reng-diao-le	dianshi,	chuang,	he	bingxiang.
animal-PLU	*all*	chuck-out-ASP	TV,	bed	and	fridge

(14) a. If *dou* selects the subject NP 'animals' as the domain:

'All of the animals chucked out a TV, a bed and a fridge.'

b. If *dou* selects the complex plural NP 'TV, bed and fridge' as the domain:

'The TV, the bed and the fridge are all chucked out by the animals.'

In adult grammar, *dou* can distribute over only the c-commanding subject NP *xiaodongwu-men*, which is within the scope of *dou* (Lee 1986; Li 1995; see also Ke et al. submitted). If *dou* quantifies over this NP, the corresponding logical form would be (15a), meaning "For every x, x an animal, x chucked out a TV, bed and fridge." However, if our grammar allows *dou* to extend its scope to the whole sentence, and, as a result, to quantify over an NP that is outside of its normal scope, the compound NP *dianshi, chuang, he bingxiang* “TV, bed and fridge” may be taken as the domain. In this case, meaning (15b) is derived: “For every x, x a TV, a bed or a fridge, animals chucked out x.” In other words, *dou* distributes the property *animals chucked out something* to every member of the domain *TV, bed and fridge*.

(15) a. $\forall x\ \big[x \in [\text{animal}]\big] \rightarrow$ x chuck out a TV, bed and fridge.

b. $\forall x\big[x \in [\text{TV, bed, fridge}]\big] \rightarrow$ animals chuck out x.

1.4 Children are competent with dou-quantification: Previous studies

Studies investigating different aspects of children’s knowledge of *dou* show that children do have core knowledge of *dou*-quantification. Lee (1986) found that children as young as four to five years old know the exhaustive force of *dou*-quantification. For a sentence like (16), children would be shown a picture of three pandas where all three pandas are sleeping (exhaustive), and another picture in which only two out of three pandas are sleeping (non-exhaustive). When asked to choose the picture best described by (16), children chose the exhaustive picture 91% of the time.

(16) Xiongmao *dou* shuijiao le.

Panda *all* sleep PTCL

'Pandas all fell into sleep.'

Hsieh (2008) did a longitudinal study of her son's production. She found that *dou* emerged in the child's production when he was 2 years old, consistent with Lee (1986). In addition, from 4 years and 2 months, the child started to consistently use *dou* together with universally quantified expressions and wh-phrases, which may imply that this child understood *dou* is obligatory as a licenser in these cases.

Zhou & Crain (2011) further confirmed that 4- to 5-year-old children give adult-like interpretation when *dou* quantifies over wh-phrases. The experimenter told subjects a story in which all of the three dogs in the context have climbed up a small tree, but only one of them has later climbed up a big tree. Then either a statement (17a) or a question (17b) was presented, and participants were asked to determine whether the sentence was a statement or a question. Participants responded with a true/false judgment if they determined the sentence to be a statement, and responded with an answer if they determined that the sentence was a question.

(17) a. shei dou meiyou pa-shang dashu.

who all not climb-up big-tree

'Everyone didn't climb up the big tree.'

b. shei meiyou pa-shang dashu?

who not climb-up big-tree

'Who did not climb up the big tree?'

A crucial difference between these two sentences is that in (17a) *dou* quantifies over the wh-phrase *shei* 'who', which brings universal force to the wh-phrase's interpretation. As a result, (17a) must be interpreted as a declarative statement, whereas (17b), which does not include *dou*, must be interpreted as a question. The target sentences were produced with the same neutral intonation pattern in order to avoid the intonation effects on the interpretation of the test sentence.

Children, as well as adults, rejected sentence (17a) 95% of the time, and they provided correct answers such as "Two dogs didn't." to (17b) 96% of the time. Zhou & Crain (2011) concluded that children know *dou* is a universal quantifier which can quantify over wh-phrases, enforcing an exhaustive interpretation. This is why when *dou* is absent, they identify the sentence correctly as a question rather than a statement.

Therefore, these studies confirm that 4 years old children know that *dou* carries universal force (exhaustivity), and *dou* can distribute over or act as a licenser for a wh-phrase or a universally quantified phrase. This answers our first research question in (8a).

2 Experiments

In this section, we explore our second research question (8b) regarding children's domain restriction in *dou*-quantification. We present data from two experiments, each including a pretest session and a main session.

2.1 Pretests

The pretests served both as a preliminary test on children's knowledge of *dou* and as a practice for participants to become familiarized with the task. In the pretests, the experimenter assured that subjects were engaged in the task. If a subject failed to answer the pretests items correctly, s/he was excluded from the data analysis. Among the children who did not provide correct answers, there were children who always answered "yes" or "no" to all sentences.

There were four pretest items in the first experiment (including two sentences with *dou* and the other two without *dou*) and one in the second experiment (a sentence with *dou*). Figure 1 shows a typical example of the pictures accompanying a simple introduction of the picture ("This story is about dogs who are looking for footballs."), as well as an example of the target sentences (either one with *dou* or one without *dou*) (18) presented after Figure 1.

Figure 1: an example of the pictures of the pretests.

(18) a. Without *dou*: Xiaogou zhaodao-le zuqiu.

dog find-ASP football

'Dog(s) found (a) football(s).'

b. With *dou*: Xiaogou dou zhaodao-le zuqiu.

dog dou found-ASP football

'Dogs all found (a) football(s).'

In the pretests for Experiment 1, participants were asked to judge whether sentences such as (18a) or (18b) was a good description of the story shown in Figure 1. Since the pretest sentences for Experiment 1were of two types, i.e. with *dou* or without *dou*, we can identify children's interpretation of *dou* by comparing their responses to the pretest items. In the second experiment, we included only a sentence with *dou*, because we were already sure that children answer "yes" to sentences without *dou* under the context as in Figure 1.

Note that Chinese does not have plural suffix as in English, so the bare noun *xiaogou* 'dog' in sentence (18a) can either refer to a single dog or many dogs. However, when the NP is quantified by *dou* as in

(18b), it must refer to all the dogs in the context, that is, the two dogs in Figure 1. The disappearance of the singular interpretation of the bare noun can thus be used as a diagnostic for *dou*-quantification. In other words, if participants know *dou* is a universal quantifier, then they are expected to say (18b) is a false description of the story, whereas the singular interpretation of the bare noun in (18a) makes this sentence a true statement under the context in Figure 1.

Results of the pretests show that 4-year-old children judged (18a), the sentence without *dou*, as a correct statement 91.7% of the time, while they rejected (18b), the sentence with *dou*, 100% of the time. [8] This is similar to adults, who accepted the sentences without *dou* up to 87%, and rejected those with *dou* 100% of the time. We thus conclude that 4- to 5-year-old children know that *dou* is a universal quantifier or a distributive operator carrying universal force.

In summary, the results of our pretests have confirmed the answer to our first question, consistent with the results in Lee (1986), Hsieh (2008) and Zhou & Crain (2011), suggesting children have acquired *dou*-quantification by 4 years old. We conclude that 4- to 5-year-old children do not have problems with the core operation in *dou*-quantification or distributive computation. However, the target sentences in the pretests are very simple, since each sentence includes only one plural NP as a candidate for the domain of *dou*. In the main test session, we want to see whether children's domain selection is the same as adults' when there are two potential candidates available for *dou*'s domain.

[8] See the subject information in the Participants sections of the two experiments.

2.2 Main Test: Experiment 1

We now present data from two experiments to answer our second research question in (8b): what are the reasons that could explain children's failure in distributive computation in some conditions? Both of the two experiments use sentences containing two candidates for the domain selection of *dou*-quantification. The crucial difference is that in the first experiment, both of the candidates are within the scope of *dou*, whereas in the second experiment, one candidate is in *dou*'s scope and the other is not.

Experiment 1 explores children's selection of domain when there are two NPs available within *dou*'s scope, both occurring to *dou*'s left and c-commanding *dou* (see Section 1.3 for a discussion on the syntactic status of prepositions in Chinese).

2.2.1 Participants

Twenty-five monolingual Chinese-speaking children (mean age: 4 years and 10 months; range from 4;1 to 5;3) participated in this experiment. Participants were recruited from the kindergarten at Beijing Language and Culture University. In addition, forty-one adults were recruited from Beijing Normal University to participate in the experiment. The data of one child subject and five adults were excluded from our analysis because they made two or more mistakes in filler items.

2.2.2 Method and Procedure

For children, we used a variant of the Truth Value Judgment Task (Crain & Thornton 1998). The task involved two experimenters. One acted out stories using pictures, and the other played the role of a puppet who watched the stories alongside the participant. After each story, the puppet would tell the participant what he thought had happened in the story using a test sentence. Participants' task was to judge whether the puppet was correct. A between-subject design was employed for the child group to limit the experiment to 45 minutes: they were divided into two groups, and each group received stimuli from one of the two conditions (see the Materials section for details). For adults, we used a questionnaire that included materials of both conditions.

2.2.3 Materials

Our first experiment included twelve target trials and twelve fillers. A typical test sentence is given in (19), as we have already discussed in (11), in which there are two NPs to the left of *dou* and c-command *dou*: *wugui* 'tortoise' and *laoying* 'eagle'[9]. Either NP can be the domain of *dou*. The test sentence was presented following a scenario depicted either as in Figure 2 under the Subject Condition (6 items; corresponding to the reading in which *dou* quantifies over the subject NP *wugui* 'tortoise') or as in Figure 3 under the Preposition Object Condition (6 items; corresponding to the reading in which *dou* distributes over the object of the preposition, *laoying* 'eagle'). The size of characters (drawings of either human or animals) was kept as similar to each other as possible. The position of the objects (the orchids

[9] Chinese does not have morphological distinctions between singulars and plurals, so both NPs in (1) can be interpreted either as a singular or as a plural.

in Figure 2 and 3) is counterbalanced across items.

(19) Wugui zai laoying pangbian *dou* zhong-le lanhua.

tortoise at eagle side *dou* plant-ASP orchid

'The tortoise(s) at the eagle(s) side all planted orchid(s).'

Figure 2: Subject Condition

Figure 3: Preposition Object Condition

The story associated with Figure 2 is as in (20).

(20) Here are two tortoises and two eagles. The tortoises want to plant orchids beside the eagles. Look, at the side of this eagle (pointing to one of the eagle) there is an orchid. Who planted it? It is this tortoise or that tortoise (pointing to the tortoises)? Yes, it is the left tortoise that planted it. What about the other orchid. Hmm, it is also planted by the left tortoise. You see, the right tortoise (pointing to the tortoise on the right side) didn't plant any orchid.

A story with the same pattern was presented when Figure 3 was shown to the subjects.

Note that when presenting the test sentences, we put the prosodic stress on *dou*, and leave the two NPs un-emphasized, in order to avoid an influence from the emphasis pattern on domain selection.

Fillers were created to ascertain if children pay attention to the test. The fillers were designed such that half would be answered "yes," and the other half "no." The results of the fillers can shed light on the participants' understanding of *dou*-quantification over the subject NP or the preposition object. The fillers were of two types; either only the subject NP was available to be quantified by *dou* (21a), or only the PP was available (21b).

(21) a. Wugui *dou* zhong-le lanhua.
tortoise *dou* plant-ASP orchid
'The tortoises all planted an orchid.'

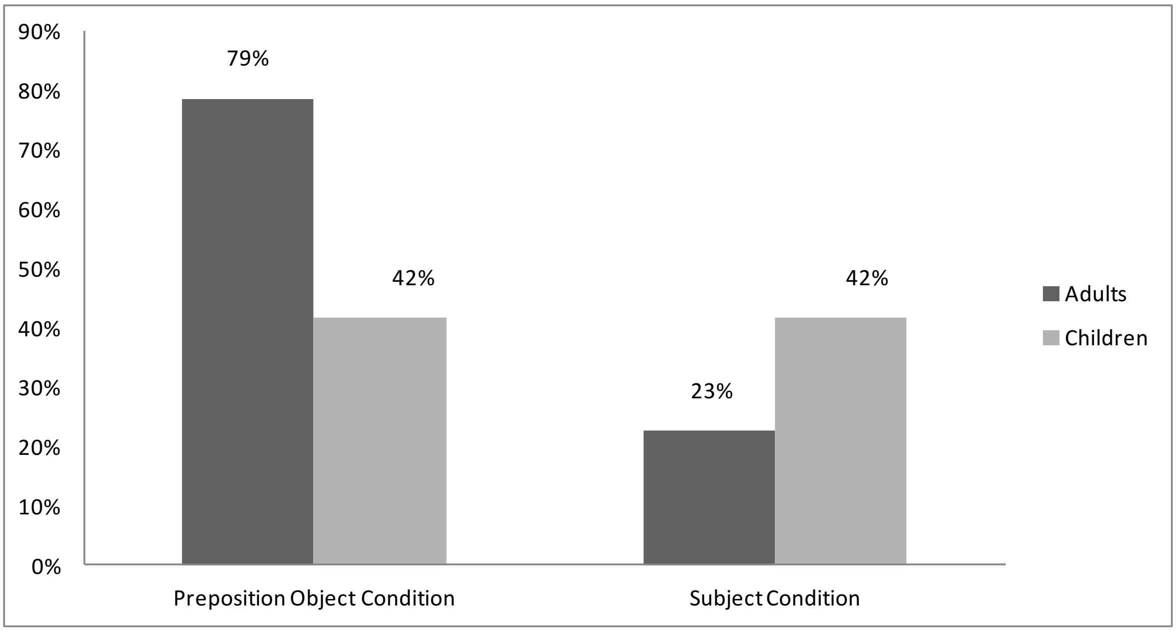
b. Laoying pangbian *dou* zhong-le lanhua.
eagle side *dou* plant-ASP orchid
'Besides all the eagle(s) there is an orchid planted.'

2.2.4 Results

The results of the 36 adults were included in the data analysis, with the other 5 adults who made more than two errors in the fillers being excluded. Data of one child (4 yr 11m) was also excluded from the analysis for the same reason. The results are presented in Figure 4.

As shown in Figure 4, adults prevailingly accepted the test sentences in the Preposition Object Condition at a rate of 79%, whereas they accepted the test sentences in the Subject Condition at a rate of only 23%. A Pearson's Chi-squared test reveals that the difference between the acceptance rates under the two conditions reaches statistical significance at α = .05, with X^2 (1, N = 432) = 133.36, p < .001. These results indicate that adults have a preference to choose the object of the preposition NP instead of the subject NP as *dou*'s domain. However, children do not have such a preference, since the acceptance rates of the test sentences under both conditions are 42%.

Figure 4: Adults' and children's acceptance rates of the test sentences in Experiment 1.



A closer examination of the individual results (Figure 5 and 6) underpins the idea that adults have a strong preference to select the object of the preposition as the domain of *dou*, whereas children do not have such a preference. We also find that the adults' and children's choice of domain is not random.

Figure 5: Acceptance rate of the test sentence of each adult participant in Experiment 1

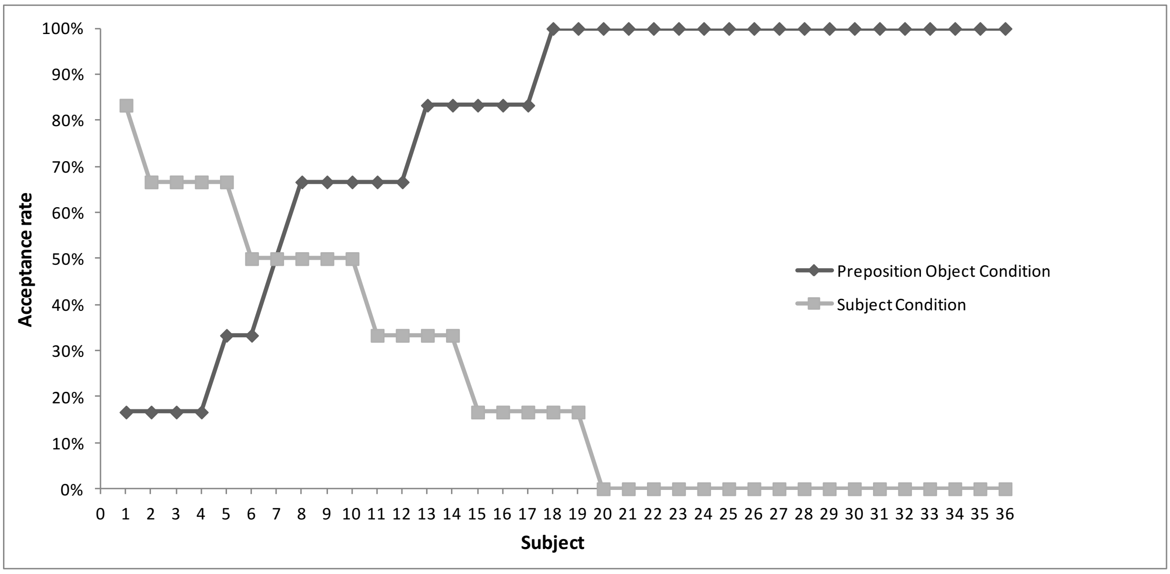
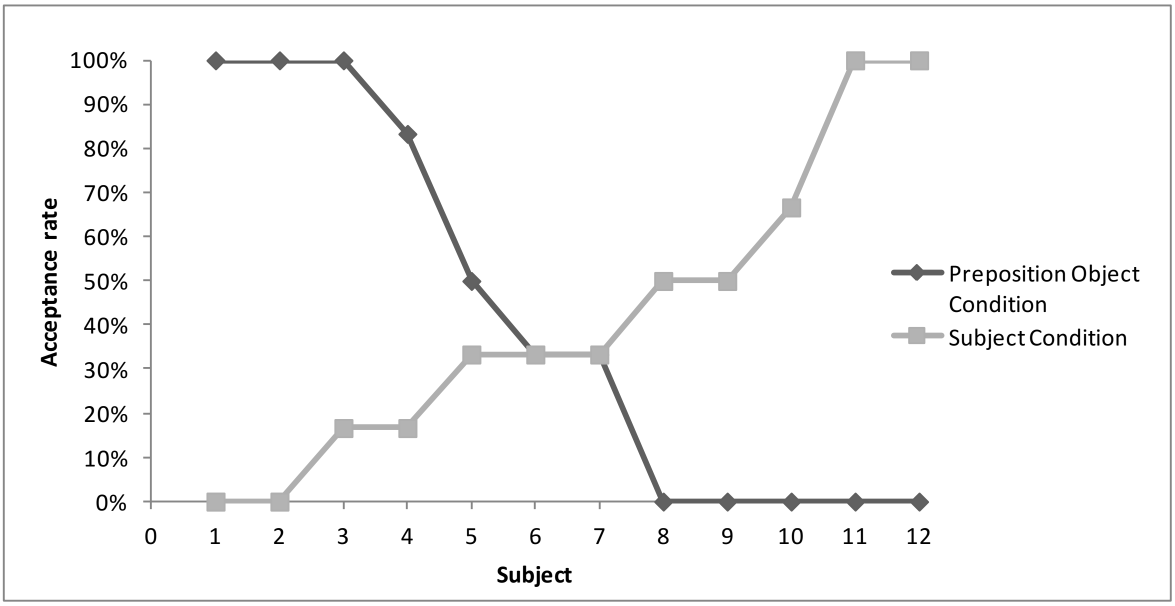


Figure 6: Acceptance rate of the test sentence of each child participant in Experiment 1



In addition, there was much variation across individuals, which suggests that their selection of domain may be based on a probabilistic mechanism, which will be discussed in detail in the General Discussion.

2.2.5 Discussion

Our results confirm Cheng's (1995) proposal regarding adults' grammar that either the subject NP or the object of the preposition can be the domain of *dou*. However, it is not predicted that the object of the preposition be taken as the domain most of the time. These results suggest that *dou* is not a strict un-selective universal quantifier (Lewis 1975; Lee 1986) that must quantify over all free variables in its scope. Indeed, if *dou* is a strict unselective universal quantifier, then we would expect that *dou* quanti-fies over both bare nouns simultaneously. The adults would therefore have rejected the test sentences in both conditions. On the contrary, it turned out that adults could accept the test sentences in either the Subject Condition or the Preposition Object Condition, although the object of the preposition is the preferred domain.

The question immediately arises as to why adults prefer to take the object of the preposition rather than the subject as the domain of *dou.* One important reason may be that the object of the preposition is linearly and structurally closer to *dou* than the subject. As we have seen in the literature review, domain selection is influenced by various salience effects. The object of the preposition may thus be more salient than the subject NP because of being linearly and structurally closer to *dou*, that is, the path between the preposition object NP node and *dou* is shorter than the path between the subject NP and *dou* (Pesetsky 1982; Lee 1986). Children accepted the test sentences under both conditions 42% of the time. These results can be interpreted in two different ways. One interpretation might be that children answer the questions randomly, and perhaps do not understand the test sentences at all. This interpretation seems quite unlikely though. First, the children displayed adult-like competence in filler items (with a correct rate of 95%), which means that they understood the meaning of *dou* and also took *dou* into consideration when judging the truth value of the filler sentences. Second, the children provided adult-like justification to support their "no" responses to test sentences. For example, when providing a reason why the test sentence (19) is false with regard to the story under the Preposition Object Condition, a child usually say "No, just one of the two eagles planted an orchid."

An alternative interpretation is that it was not easy for child participants to select a proper NP as the domain of *dou* in this case. These two NPs are syntactically close to each other, and since both of them are available to be the domain of *dou*, children are predicted to experience much interference when computing the domain of *dou*. According to Lewis and colleagues' (Lewis & Vasishth 2005; Lewis et al. 2006; Vasishth et al. 2008) feature-based retrieval model, when *dou* is encountered, the parser needs to retrieve its domain. Both of the NPs will be retrieved because they share almost all features, giving rise to severe interference effects. In other words, when children consider one of the NPs as the domain, another NP is also retrieved as an appropriate domain. Consequently, it appears that children randomly picked one of the NPs as the domain. This conjuncture is supported by a recent study showing that children were temporarily more distracted than adults when multiple retrieval cues supported a prominent competitor antecedent in the processing of reflexive binding (Clackson et al. 2011).

Adults, on the other hand, may employ pragmatic reasoning based on the distribution of cases of *dou*-quantification. That is, when *dou* is located immediately after the subject NP as in (22), it unambiguously quantifies over the subject NP. Therefore, adults may perceive *dou*'s being located after the PP as a pragmatic cue that *dou* quantifies over the prepositional object. In other words, if the speaker intended *dou* to quantify over the subject NP, why use an ambiguous construction instead of the unambiguous (22)? A *reasonable* hypothesis then is that adults are sensitive to this pragmatic cue, but children, who are known to generally lack adult-like pragmatics, are not.[10]

(22) Wugui *dou* zai laoying pangbian zhong-le lanhua.
tortoise *dou* ate agle side plant-ASP orchid
'The tortoises all planted orchids beside the eagle(s).'

In order to further investigate children's strategy in domain restriction, another experiment was conducted in which the two plural NPs, the subject and the object, were separated, with the subject placed inside the scope of *dou* and the object outside. We are interested in whether children can extend the scope of *dou* to the object NP and take the object NP as the domain. [11]

2.3 Experiment 2

The second experiment was designed to investigate adults and children's selection of the domain of *dou*,

[10] Of course, this hypothesis needs some further justification. Another alternative explanation is that adults are more sensitive to closeness effects, possibly due to syntactic principles such as Cheng's (1995) Principle of Economy of Derivation on *dou*-quantification. On the other hand, children are not so sensitive to such effects. We will not make commitment to any of these alternatives until strong evidence can be provided.

[11] Since we have confirmed that children do not have problems taking the subject NP as the domain of *dou*, as has been shown in the pretests and the fillers in our experiments, here we only test whether children can extend the scope of *dou* to the object NP. The results of the present experiment, however, do show that children can quantify over the subject NP.

and to test whether children will extend the scope to the object NP.

2.3.1 Method

Again, we used a variant of Truth Value Judgment Task.

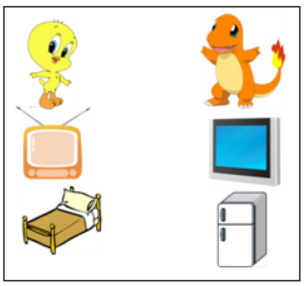
2.3.2 Participants

Twelve children (mean age 4 years and 11 months, range from 4;7 to 5;1) at the kindergarten of Beijing Language and Culture University participated in this experiment. Eighteen adults, all postgraduate students recruited from Beijing Normal University, served as controls, taking questionnaires with the same materials.

2.3.3 Materials

Each subject received one pretest, four test items and four fillers. Pretests used a sentence with *dou*. A typical example of the test sentences, as well as the pictures accompanying the stories, can be seen in Figure 7 and sentence (23).

Figure 7: a typical context of Experiment 2.



(23)	Xiaodongwu-men	dou	reng-diao-le	dianshi,	chuang,	he	bingxiang.
	animal-PLU	all	chunked-away-ASP	TV,	bed,	and	fridge

‘The animals all chucked a TV, bed and fridge out.’

The test sentence (23) was presented following a story corresponding to Figure 7, in which one animal (the Tweety Bird) chuked a TV and a bed away, and the other (the dinosaur) chucked a TV and a fridge out.

As we have mentioned, *dou* may distribute over only the NPs that c-command it. In (23), *dou* should distribute over only the subject NP *xiaodongwumen* ‘animals’ which c-commands *dou*. The conjunct object NP *dianshi, chuang, he bingxiang* ‘TV, bed, and fridge’, which does not c-command *dou*, is impossible as the domain of *dou*. This is a good case for us to test whether children can extend the scope of *dou* to an NP that does not c-command it and take that NP as the domain of *dou*.

The prediction is that if *dou* distributes over *xiaodongwu-men* ‘animals’ in (23), the derived interpretation will be ‘each of the animals chucked a TV, bed, and fridge out’, as is translated in (24); if *dou* distributes over the conjunct NP *dianshi, chuang, he bingxiang* ‘TV, bed, and fridge’, the meaning ‘for the TV, bed and fridge, each of them was chunked away by the animals’ as in (25) will be derived. According to the story presented with Figure 7, (24) is false and (25) is true.

(24) ∀x [x∈[[animals]] → x chuck out a TV, bed, and fridge]

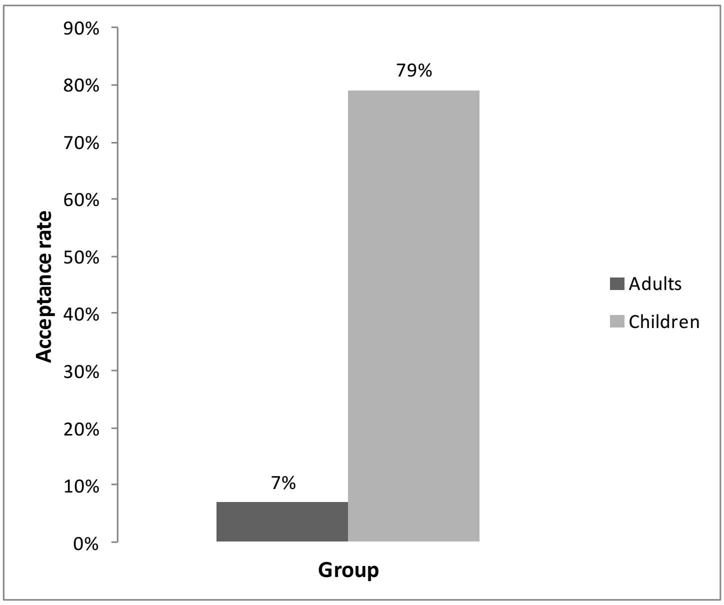
(25) ∀x [x∈[[TV-bed-and-fridge]] → animals-chuck-out x]

In addition to the test trials, each subject saw four fillers. Fillers were designed to verify whether children paid attention to the tasks by asking them simple questions about the stories. Furthermore, we used fillers to diversify the statement patterns, in order to conceal the purpose and the inherent pattern of the target trials. For instance, given the context such as Figure 7, a filler would be *Xiaoniao zhaodao le dianshi, dui haishi budui?* ‘The Tweety Bird found a TV, true or false?’ Children were expected to give a “No/Yes” answer.

2.3.4 Results

All the subjects, including adults and children, accepted or rejected the filler items at an accuracy rate of 100%, so all the data were included in the analysis. The findings shown in Figure 8 are that children accepted the test sentences 79% of the time, and rejected them only 21% of the time. The reasons provided by children showing that the rejection of the test sentences were because they assigned the subject NP as the domain of *dou*. In contrast, adults overwhelmingly rejected the test sentence by 93%. We performed a Pearson's Chi-squared test in R (R Core Team 2014), which shows that children accepted the test sentences much more often than adults, with X^2 (1, 121) = 62.23, p < .001.

Figure 8: Acceptance rate of the test sentences of children and adults in Experiment 2



2.3.5 Discussion

The fact that almost all of the adults rejected the target sentences shows their firm compliance with the c-command requirement with regard to the distributive computation of *dou*. Adults were reluctant to select the domain from the NPs outside the scope of *dou*. On the other hand, 4- to 5-year-old children showed great flexibility of domain restriction concerning distributive computation, because they can take an NP that is outside of the scope of *dou* as the domain of *dou*.[12]

These results support the idea that children are more flexible than adults in restricting the domain of

[12] Another possibility that might have led to children's acceptance of the test sentence is that children might ignore *dou* in the test sentence, and a collective reading is resulted, which makes the sentence true under the designed context. This is very unlikely though, because we have shown clearly in the results of the pretests, children distinguish sentences with *dou* from sentences without *dou*. The perfect results from the fillers of Experiment 1 also strongly confirm that children would not ignore *dou*.

the distributive operator *dou*. When more than one plural NP is present, it is possible for children to take either of them to be the domain of *dou*, even in cases when an NP is outside the syntactic scope of *dou*.

These results also shed light on the problem raised in the first experiment. It was the syntactic closeness and similarities between the two NPs that might have caused severe interference effects in domain selection to children, resulting in difficulties to identify a proper domain. Therefore, when the two NPs were separated and these interference effects were reduced, children could easily select the NP that is outside of the scope of *dou* as its domain. The rejection rate of the test sentences was 21%, suggesting that sometimes children may consider it obligatory to take the c-commanding subject NP as the domain. The acceptance and rejection data together thus indicate that children can take either NP as the domain of *dou*.

Given that children are rather flexible in the domain restriction of *dou*-quantification, there must be reasons why the object NP was selected most of time as the domain. Several factors may have contributed to this bias. First, it has been reported that children would be willing to say “yes” instead of “no” when the test sentence is ambiguous and one of the interpretations can make the test sentence true (Crain & Thornton 1998). Second, the object NP is a complex NP, which may be more salient than the subject NP. The second point can be tested further with an experiment where the number of the NPs inside the conjunct NP reduced, to see if the acceptance rate of the object complex NP would decrease.

In summary, the results of the first experiment reveal that adults show a preference to take the object of the preposition as the domain of *dou*, compared to the subject NP, possibly due to pragmatic cues. Children, on the other hand, do not have such a preference. Children thus are rather free to choose either

NP as *dou*'s domain. The second experiment reinforces the argument that children are much more flexible on domain restriction with the finding that children are able to take an NP which is outside its scope as the domain.

3 General Discussion

Compared to adults, four- to five-year-old children were more flexible on domain restriction, being insensitive to syntactic principles that adults apply to delimit the scope of *dou* (and possibly pragmatic cues with regard to competitive *dou*-constructions). However, the non-adult behavior does not imply that four- to five-year-old children are simply incompetent with *dou*-quantification/distribution. Actually, the results of our pretests, as well as the previous studies of Lee (1986), Hsieh (2008) and Zhou & Crain (2011), indicate that four- to five-year-old children have full grammatical competence with *dou*-distribution.

In order to account for children's seemingly contradictory performance, an explanation that could reconcile the results from the current and previous studies is desirable. We argue that 4-year-old children are able to execute the core computational procedure of distributive operator. Children have the knowledge that a distributive operator distributes the property denoted by the VP to the domain. The non-adult interpretations of children can be attributed to the fact that children assign a different domain to the distributive operator than adults do. We propose that children will become adult-like in processing distributive quantifiers once they consistently assign the same domain as adults do.

Now we are ready to return to the phenomenon *quantifier spreading* reviewed in the introduction.

Recall that many researchers found that children have knowledge of universal quantification, but their selection of domain is affected by various salience effects.

Our results show that it may be true that the knowledge of universal quantification is innate, and thus it must emerge in an early age. But, as noted by Philip (2011), children should also acquire other knowledge that apply to the universal quantifiers:

"(i) [a universal quantifier] must have a semantic restriction provided by the denotation of an NP; (ii) only one NP can have this function; and (iii) this NP must always be identified by some rule" (Philip 2011:359). For our experiments, we found that children as young as 4-5 have the knowledge that *dou* should distribute over a semantic domain, and they were certainly capable of processing the sentence with a single NP as the domain of *dou* (Philip's 1st point). Furthermore, the children take only one NP as the domain (Philip's 2nd point), rather than simultaneously quantifying over every NP that is available, as was shown in both experiments. However, they have problems when selecting a proper domain from two potential NP candidates. A plausible reason is that they are insensitive to rules that are responsible for the identification of the proper NP for the domain (Philip's 3rd point). This is what Philip predicted:

"There must be some grammatical rules or other which always selects an NP in a specific syntactic position as the source of its semantic restriction. However, it is not necessary for UG to spell out exactly what the rules in question are by supplying parameters that need to be set. This is because the actual rules can straightforwardly be learned as constructions from positive evidence." (Philip, 2011, p. 360)

Our results suggest that four- to five-year-old Chinese speaking children abide by the c-command requirement in a fairly flexible and loose way; they permit an NP outside of *dou*'s scope to be *dou*'s domain. The flexibility of domain restriction may also account for their non-adult performance in quantifier spreading (cf. Freeman & Stedmon 1986). When they hear the sentence *every girl is riding a bike*, some of them may choose *bike* as the domain of *every*, by extending the scope of *every* to the whole sentence (cf. Roeper et al. 2001; Roeper et al. 2005; Roeper et al. 2011). As the scope of *every* is extended to the whole sentence, the NP that is more salient is naturally more readily selected as the domain. We thus explain why the salience status of an NP has a considerable impact on domain selection. On the contrary, adults comply more strictly with the principle that the quantifier *every* needs to quantify over its syntactic complement, the NP *girl*.

We assume the following principle (26) to account for young children's symmetrical responses and various salience effects. Children should be able to acquire (26a) at an early age, because as noted by Philip (2011) the knowledge of universal quantification is plausibly innate. Previous studies have shown that the knowledge is firmly established by 5 years old.[13]

(26) a. **Universal quantification:** *every*, as a determiner universal quantifier, quantifies over its

[13] At 4 or younger, children make the Un-Mentioned Object Spreading (Philip 1995; Roeper et al. 2005), in which children said 'no' to the test sentence **Error! Reference source not found.**) when the extra object is not mentioned in the test sentence. In the same age range, children also make another type of errors by providing under-exhaustive answers (Gavarró & Álvarez 2011; Gavarró et al. 2015; Aravind et al. 2017), which are 'no' answers to sentence **Error! Reference source not found.**) when there is an extra agent in the picture. Both of these errors disappear in 5 years olds. These data indicate that 4 years old and younger children's grammar is not strictly executing (26a), and the errors are possibly because of non-linguistic reasons. (26a) is stably implemented among 5 years old children.

domain.

b. **Domain restriction**: *every*'s domain is probabilistically restricted to the NP it merges with. Children take this NP as *every*'s domain probabilistically with some parameter p_i that varies across individuals.

c. **Salience effects**: The distribution of this probability p_i is shifted to the NP that is comparatively more salient.

The domain restriction in (26b) is not innate, but is more like a learned probabilistic principle. Previous studies have shown that children continue to make quantifier spreading "errors", and that quantifier spreading does not fade away among eight- to nine-year-olds (Roeper et al. 2005; Roeper et al. 2011; Aravind et al. 2017). Importantly, quantifier spreading is not eliminated abruptly even after children are 8 or 9 years old; on the contrary, the percentage decreases gradually until children are 12 years old or even older. In fact, quantifier spreading can also be found in adults with the extra object design (Brooks & Sekerina 2006; Minai et al. 2012), which means that the probability of making quantifier spreading errors is never 0. A probabilistic approach such as (26b) thus is more compatible with the observed gradual emergence adult-style grammar than an absolute rule-based approach. The probabilistic nature of domain restriction opens a window for salience effects in domain selection (26c).

The question immediately arises how the domain restriction (26b) can be a probabilistic constraint. Our tentative answer is that the domain restriction is acquired with probabilistic learning mechanisms such as the ones that are advocated by Yang (2000b; 2002; 2004) and Lidz and colleagues (Lidz 2010;

Lidz & Gagliardi 2015). Yang (2002; 2004) argued that a combination of Universal Grammar (UG) and statistical learning can account for child language acquisition better than statistical learning alone. UG defines the hypothesis space of possible grammars, and constrains it with parameters. Statistical learning then uses the mechanism in (27) to select grammars that are consistent with linguistic input.

(27) For an input sentence, *s*, the child:

(i) with probability P_i selects a grammar G_i,

(ii) analyzes s with G_i,

(iii) if successful, reward G_i by increasing P_i,

otherwise punish G_i by decreasing P_i.

In the case of quantifier spreading, the two grammars are G_1, the target grammar, and G_2, a competing grammar. G_1 selects the NP that *every* merges with as the domain, and G_2, a competing grammar, selects a different NP. In order to select a different NP, *every* must extend its scope to the whole sentence.[14] An important difference between G_1 and G_2 is thus whether the scope of *every* can be extended or not. When **Error! Reference source not found.**), repeated in (28), is concerned, we consider the three possible conditions in the primary linguistic input as in (29): one-to-one matching condition, extra agent

[14] If *every* must c-command an NP in order to take that NP as the domain, this requirement can be achieved by mechanisms such as quantifier raising, targeting the specifier of matrix CP.

condition and extra object condition (c.f. Kang 2001).

(28) Every pig is eating an apple.

(29) a. one-to-one matching condition b. Extra agent condition c. Extra object condition

PIG	PIG	PIG
APPLE	APPLE	APPLE

PIG	PIG	PIG	PIG
APPLE	APPLE	APPLE	

PIG	PIG	PIG	
APPLE	APPLE	APPLE	APPLE

Both G_1 or G_2 can successfully analyze the input under the one-to-one matching condition. We therefore expect (28) to be the easiest for young children to parse under the one-to-one matching condition. This gives a neat explanation to the fact that children prefer to choose pictures with one-to-one matching over pictures with an extra object or agent after hearing sentences such as (28) (Brooks & Braine 1996; Brooks et al. 2001; Kuznetsova et al. 2007).

With regard to the extra agent condition (29b), since the agent is more salient, we expect the domain of *every* to be primarily the subject NP. That is, G_1 will most likely be selected to parse (28) according to the salience effects in (26c). This predicts that the majority of children's answers should be "no". This prediction is substantiated by data from Roeper et al. (2005), Gavarró & Álvarez (2011), Gavarró et al. (2015) and Aravind et al. (2017).

The most crucial case is the extra object condition. If G_1 is selected, children will say "yes" to the test sentence; if G_2 is selected, the opposite result is obtained. As we have argued, the extra object gives a salient status to the object NP, so, according to Yang's (2002; 2004) model in (27), when P_1 the probability of G_1 is roughly equal to the probability of G_2, G_2 can be selected more than 50% of the time. Four- to five-year-old children are likely in this stage. We thus expect four- to five-year-old children to say "no" to the test sentence more than 50% of the time under the one extra object condition. Again, this prediction is verified by many of the previous studies, as long as other salience effects are not also involved (Gouro et al. 2001; Kang 2001; Sugisaki & Isobe 2001; Drozd & van Loosbroek 2006; O'Grady et al. 2010; Roeper et al. 2011; Minai et al. 2012; Aravind et al. 2017).

4 Conclusions

We presented two experiments investigating children's domain selection of *dou*-quantification. Both experiments reveal that children behave differently from adults in the domain restriction of *dou*. The first experiment shows that adults have a preference to select the closer NP as the domain of *dou*, whereas children do not have such a preference. A plausible explanation that awaits future justification is that children are not sensitive to a pragmatic cue regarding the distribution of *dou*. The second experiment indicates that children allow an NP that is not inside the scope of *dou* to serve as *dou*'s domain, whereas this is not possible for adults. Therefore, it seems that in children's grammar *dou*'s domain is not restricted in the same way as in adults' grammar.

Children's non-adult behavior in domain restriction of universal quantification/distributivity sheds light on their general difficulties with universal quantification such as quantifier spreading. Quantifier spreading in English-speaking children can be accounted for if children do not have a proper restriction of the domain regarding *every*-quantification. This explanation is consistent with previous findings concerning various salience effects in quantifier spreading; an NP that is more salient than others is more readily selected as the domain of *every*, regardless of whether this NP is inside the scope of *every* or not. The flexibility and probability feature of children's domain restriction is derived and explained by Yang's (2002, 2004) language acquisition model.

References

Aravind, Athulya, Jill de Villiers, Peter de Villiers, Christopher J. Lonigan, Beth M. Phillips, Jeanine Clancy, Susan H. Landry, Paul R. Swank, Michael Assel, Heather B. Taylor, Nancy Eisenberg, Tracy Spinrad, & Carlos Valiente. 2017. Children's quantification with *every* over time. *Glossa: a journal of general linguistics*. 2 (1). DOI: http://doi.org/10.5334/gjgl.166.

Arnold, Jennifer. 1999. *Marking salience: The similarity of topic and focus*. University of Pennsylvania. Access at.

Brooks, Patricia J., & Martin D.S. Braine. 1996. What do children know about the universal quantifiers all and each? *Cognition*. 60 (3). 235-268.

Brooks, Patricia J., Martin D.S. Braine, Gisela Jia, & Maria da Graca Dias. 2001. Early representations for all, each, and their counterparts in Mandarin Chinese and Portuguese. In Melissa Bowerman & Stephen C. Levinson (eds.), *Language acquisition and conceptual development*, 316. Cambridge, United Kingdom: Cambridge University Press.

Brooks, Patricia J., & Irina Sekerina. 2006. Shortcuts to Quantifier Interpretation in Children and Adults. *Language Acquisition*. 13 (3). 177-206. DOI: 10.1207/s15327817la1303_2.

Chen, Liping. 2008. *Dou: Distributivity and beyond*. New Brunswick, NJ: Rutgers, The State University of New Jersey dissertation.

Cheng, Lisa Lai-Shen. 1995. On "*dou*" quantification. *Journal of East Asian Linguistics*. 4 (3). 197-234. DOI: 10.1007/BF01731509.

Cheng, Lisa Lai-Shen. 2009. On Every type of quantificational expression in Chinese. In A. Giannakidou & M. Rathert (eds.), *Quantification, Definiteness, & Nominalization*, 53-75. Oxford: Oxford University Press.

Chiu, Bonnie Hui-Chun. 1993. *The Inflectional Structure of Mandarin Chinese*. Los Angeles, CA: University of California, Los Angeles dissertation.

Chomsky, Noam. 1991. Some notes on economy of derivation and representation. In R. Freidin (ed.), *Principles and Parameters in Comparative Grammar*, 417-454. Cambridge, MA: MIT Press.

Clackson, Kaili, Claudia Felser, & Harald Clahsen. 2011. Children's processing of reflexives and pronouns in English: Evidence from eye-movements during listening. *Journal of memory and language*. 65 (2).

128-144. DOI: http://dx.doi.org/10.1016/j.jml.2011.04.007.

Cowles, H. Wind, Matthew Walenski, & Robert Kluender. 2007. Linguistic and cognitive prominence in anaphor resolution: topic, contrastive focus and pronouns. *Topoi*. 26 (1). 3-18. DOI: 10.1007/s11245-006-9004-6.

Cowles, Wind. 2006. *Processing information structure: Evidence from comprehension and production*: University of California, San Diego Ph.D. dissertation.

Crain, Stephen, & Rosalind Thornton. 1998. *Investigations in Universal Grammar: A guide to experiments on the acquisition of Syntax and Semantics*. Cambridge, MA: the MIT Press.

Crain, Stephen, Rosalind Thornton, C. Boster, L. Conway, D. Lillo-Martin, & E. Woodams. 1996. Quantification without qualification. *Language Acquisition*. 5 (2). 83-153. DOI: 10.1207/s15327817la0502_2.

Csibra, Gergely, & György Gergely. 2009. Natural pedagogy. *Trends in Cognitive Sciences*. 13 (4). 148-153. DOI: http://dx.doi.org/10.1016/j.tics.2009.01.005.

Drozd, Kenneth. 2001. Children's weak interpretations of universally quantified questions. In Melissa Bowerman & Stephen C. Levinson (eds.), *Language Acquisition and Conceptual Development*, 340-376. Cambridge, MA: Cambridge University Press.

Drozd, Kenneth F. 2004. Learnability and linguistic performance. *Journal of Child Language*. 31 (02). 431-457.

Drozd, Kenneth, Julien Musolino, & Heather K.J. van der Lely. submitted. *Processing of Universal Quantification in Typically Developing Children and Children with Grammatical SLI*. Ms.

Drozd, Kenneth, & Erik van Loosbroek. 2006. The effect of context on children's interpretations of universally quantified sentences. In Veerle van Geenhoven (ed.), *Semantics Meets Acquisition*, 115-140. Dordrecht, Netherlands: Kluwer Acedemic Publishers.

Freeman, N.H. 1985. Reasonable errors in basic reasoning. *Educational Psychology*. 5 (3-4). 239-249.

Freeman, Norman H, Chris G Sinha, & Jacqueline A Stedmon. 1982. All the cars—which cars? From word meaning to discourse analysis. In Michael Beveridge (ed.), *Children thinking through language*, 52-74. London: Edward Arnold Publisher.

Freeman, Norman H., & Jacqueline A. Stedmon. 1986. How Children Deal with Natural Language Quantification. *Advances in Psychology*. 39. 21-48. DOI: http://dx.doi.org/10.1016/S0166-4115(09)60131-X.

Gavarró, Anna, & M Álvarez. 2011. A pilot study of quantification in child Catalan. *Zeitschrift für Katalanistik*. 24.

Gavarró, Anna, Anna Lite, & S Stavrakaki. 2015. Universal quantification in Catalan SLI. In Stavroula Stavrakaki (ed.), *Specific language impairment: Current trends in research*, 191-213. Amsterdam/Philadelphia: John Benjamins Publishing Company.

Geurts, Bart. 2003. Quantifying Kids. *Language Acquisition*. 11 (4). 197-218. DOI: 10.1207/s15327817la1104_1.

Geurts, Bart, & Bob van Tiel. 2015. When “All the Five Circles” are Four: New Exercises in Domain Restriction. *Topoi*. 1-14. DOI: 10.1007/s11245-014-9293-0.

Giannakidou, Anastasia, & Lisa Lai-Shen Cheng. 2006. (In) Definiteness, Polarity, and the Role of wh-morphology in Free Choice. *Journal of Semantics*. 23 (2). 135-183. DOI: 10.1093/jos/ffl001.

Gordon, Peter. 1998. The truth-value judgment task. In Dana McDaniel, Cecile Mckee & Helen Smith Cairns (eds.), *Methods for assessing children’s syntax*. Cambridge, MA: The MIT Press.

Gouro, Takuya, Hanae Norita, Motoki Nakajima, & Ken-ichi Ariji. 2001. Children's interpretation of universal quantifier and pragmatic interference. the *Proceedings of the Second Tokyo Conference on*

Psycholinguistics, 61-78. Tokyo: Hituzi Shobo Publishing Company.

Grimshaw, Jane, & Sara Thomas Rosen. 1990. Knowledge and Obedience: The Developmental Status of the Binding Theory. *Linguistic Inquiry*. 21 (2). 187-222. DOI: 10.2307/4178669.

Gualmini, Andrea, Luisa Meroni, & Stephen Crain. 2003a. An asymmetric universal in child language. *Proceedings of Sinn und Bedeutung VI*. 136-148.

Gualmini, Andrea, Luisa Meroni, & Stephen Crain. 2003b. Children's asymmetrical responses. the *Proceedings of Proceedings of the Fourth Tokyo Conference on Psycholinguistics*, 135-158.

Haider, Hubert, Christina Schörghofer-Essl, & Karin Seethaler. 2017. Quantifying kids prefer intersecting sets–a pilot study. *Zeitschrift für Sprachwissenschaft*. 36 (1). 31–50. DOI: https://doi.org/10.1515/zfs-2017-0003.

Heim, Irene. 1982. *The Semantics of Definite and Indefinite Noun Phrases*. Amherst, MA: University of Massachusetts at Amherst dissertation.

Hollebrandse, Bart. 2004. Topichood and quantification in L1 Dutch. *International Review of Applied Linguistics in Language Teaching (IRAL)*. 42 (2). 203-215. DOI: 10.1515/iral.2004.010.

Hollebrandse, Bart, & Erik-Jan Smits. 2005. The Acquisition of the Weak–Strong Distinction: The Case of the Dutch Quantifier. *Belgian journal of linguistics*. 19 (1). 247-264.

Hsieh, Miao-Ling. 2008. Acquiring scope: A longitudinal study. *Taiwan Journal of Linguistics*. 6. 55-96.

Kang, Hye-Kyung. 2001. Quantifier spreading: linguistic and pragmatic considerations. *Lingua*. 111 (8). 591-627. DOI: http://dx.doi.org/10.1016/S0024-3841(00)00042-5.

Ke, Alan Hezao, Samuel David Epstein, Richard Lewis, & Acrisio Pires. submitted. The quantificational domain of dou: An experimental study.

Kiss, Katalin É., & Tamás Zétényi. 2017. Quantifier spreading: children misled by ostensive cues. *Glossa: a journal of general linguistics*. 2 (1). 38. 31–20. DOI: http://doi.org/10.5334/gjgl.147.

Kuznetsova, Julia, Maria Babyonyshev, Jodi Reich, Lesley Hart, & Elena Grigorenko. 2007. The acquisition of universal quantifiers in Russian. In Alyona Belikova, Luisa Meroni & Mari Umeda (eds.), the *Proceedings of the 2nd conference on Generative Approaches to Language Acquisition North America (GALANA)*, 224-232. Somerville, MA: Cascadilla Proceedings Project.

Lee, Thomas Hun-tak. 1986. *Studies on quantification in Chinese*. Los Angeles, CA: University of California, Los Angeles dissemination.

Lewis, David. 1975. Adverbs of quantification. In E.L. Keenan (ed.), *Formal Semantics of Natural Language*, 3-15. Cambridge, MA.: Cambridge University Press.

Lewis, Richard L., & Shravan Vasishth. 2005. An Activation-Based Model of Sentence Processing as Skilled Memory Retrieval. *Cognitive Science*. 29 (3). 375-419. DOI: 10.1207/s15516709cog0000_25.

Lewis, Richard L., Shravan Vasishth, & Julie A. Van Dyke. 2006. Computational principles of working memory in sentence comprehension. *Trends in Cognitive Sciences*. 10 (10). 447-454. DOI: http://dx.doi.org/10.1016/j.tics.2006.08.007.

Li, Jie. 1995. *Dou* and wh-questions in Mandarin Chinese. *Journal of East Asian Linguistics*. 4 (4). 313-323. DOI: 10.1007/bf01440731.

Lidz, Jeffrey. 2010. Language learning and language universals. *Biolinguistics*. 4 (2-3). 201-217.

Lidz, Jeffrey, & Annie Gagliardi. 2015. How Nature Meets Nurture: Universal Grammar and Statistical Learning.

Annual Review of Linguistics. 1 (1). 333-353. DOI: 10.1146/annurev-linguist-030514-125236.

Lin, Jo-wang. 1996. *Polarity licensing and wh-phrase quantification in Chinese*. Amherst, MA: University of Massachusetts at Amherst dissertation.

Lin, Jo-wang. 1998. Distributivity in Chinese and its Implications. *Natural Language Semantics*. 6 (2). 201-243. DOI: 10.1023/a:1008299031574.

Liu, Mingming. 2016. *Varieties of alternatives*. New Brunswick, NJ: Rutgers, The State University of New Jersey Ph.D. dissertation.

Liu, Mingming. 2017. Varieties of alternatives: Mandarin focus particles. *Linguistics and Philosophy*. 40 (1). 61-95. DOI: 10.1007/s10988-016-9199-y.

Liu, Mingming. In press. Mandarin *dou*: the common core of distributivity, maximality, and EVEN., the *Proceedings of Sinn und Bedeutung (SuB) 21*.

Meroni, Luisa, Andrea Gualmini, & Stephen Crain. 2000. A conservative approach to quantification in child language. the *Proceedings of Proceedings of the 24th Penn Linguistics Colloquium*, 171-182. University of Pennsylvania Working Papers in Linguistics.

Minai, Utako. 2006. *Everyone knows, therefore every child knows: An investigation of logico-semantic competence in child language*: University of Maryland Ph.D. dissertation.

Minai, Utako, Nobuyuki Jincho, Naoto Yamane, & Reiko Mazuka. 2012. What hinders child semantic computation: children's universal quantification and the development of cognitive control. *Journal of Child Language*. 39 (05). 919-956.

Notley, Anna, Britta Jensen, & Francesco-Alessio Ursini. 2008. The early stages of universal quantification. the *Proceedings of The Proceedings of the 9th Tokyo Conference on Psycholinguistics (TCP)*, 273-300.

O'Grady, William, Takaaki Suzuki, & Naoko Yoshinaga. 2010. Quantifier Spreading: New Evidence from Japanese. *Language Learning and Development*. 6 (2). 116-125. DOI: 10.1080/15475440903352799.

Pesetsky, David Michael. 1982. *Paths and categories*. Cambridge, MA.: MIT Ph.D. dissertation.

Philip, William. 1995. *Event Quantification in the Acquisition of Universal Quantification*. Amherst, MA: University of Massachusetts at Amherst dissertation.

Philip, William. 2004. Clarity of purpose in L1 acquisition research: a response to Ken Drozd's Learnability and linguistic performance. *Journal of Child Language*. 31 (2). 496-499. DOI: 10.1017/s0305000904006154.

Philip, William. 2011. Acquiring Knowledge of Universal Quantification. In J. de Villiers & T. Roeper (eds.), *Handbook of Generative Approaches to Language Acquisition*, 351-394: Springer.

R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

Rakhlin, Natalia. 2007. A new pragmatic account of quantifier-spreading. *Nanzan Linguistics*. 8. 239-282.

Rakhlin, Natalia. 2009. Does “Q-Spreading” Come with Presupposition Spreading? , the *Proceedings of the Fourth Tokyo Conference on Psycholinguistics*, 135-158.

Roeper, Tom, & Jill de Villiers. 1991. The Emergence of Bound Variable Structures. Paper presented at *University of Massachusetts Occasional Papers Special Edition: Papers in the Acquisition of WH*, Amherst, MA.

Roeper, Tom, Barbara Zurer Pearson, & Margaret Grace. 2011. Quantifier Spreading is not Distributive. In Nick Danis, Kate Mesh & Hyunsuk Sung (eds.), the *Proceedings of Proceedings of the 35th Annual Boston on*

Language Development (BUCLD 35), 526-539. Cascadilla Press.

Roeper, Tom, E. Ramos, H. Seymour, & L. Abdul-Karim. 2001. Language Disorders as a Window on Universal Grammar: An Abstract Theory of Agreement for IP, DP, and V-PP. *Brain and Language*. 77. 20.

Roeper, Tom, Uri Strauss, & Barbara Zurer Pearson. 2005. The Acquisition Path of the Determiner Quantifier Every: Two Kinds of Spreading.

Smits, Erik-Jan, Tom Roeper, & Bart Hollebrandse. 2008. Children's ambiguous understanding of weak and strong quantifiers. *Nordlyd*. 34 (3).

Sugisaki, Koji, & Miwa Isobe. 2001. Quantification without qualification without plausible dissent. In Ji-Yung Kim & Adam Werle (eds.), the *Proceedings of SULA 1: Semantics of Under-Represented Languages in the America*, 97-100. Amherst, MA: GLSA Publications.

Tsai, Cheng-Yu Edwin. 2014. Unifying Mandarin *dou*-constructions. In Thuy Bui & Deniz Özyıldız (eds.), the *Proceedings of the 45th Annual Meeting of the North East Linguistic Society (NELS 45)*, 165-174.

Tsai, Cheng-Yu Edwin. 2015. *Toward a Theory of Mandarin Quantification*. Cambridge, MA: Harvard University dissertation.

Vasishth, Shravan, Sven Brüssow, Richard L. Lewis, & Heiner Drenhaus. 2008. Processing Polarity: How the Ungrammatical Intrudes on the Grammatical. *Cognitive Science*. 32 (4). 685-712. DOI: 10.1080/03640210802066865.

Wu, Jianxin. 1999. *Syntax and Semantics of Quantification in Chinese*. College Park, MD: University of Maryland dissertation.

Xiang, Ming. 2008. Plurality, maximality and scalar inferences: A case study of Mandarin *Dou*. *Journal of East Asian Linguistics*. 17 (3). 227-245. DOI: 10.1007/s10831-008-9025-9.

Xiang, Yimei. 2016a. *Interpreting Questions with Non-exhaustive Answers*. Cambridge, MA: Harvard University Ph.D. dissertation.

Xiang, Yimei. 2016b. Mandarin particle *dou*: A pre-exhaustification exhaustifier. In Christopher Piñón (ed.), *Empirical Issues in Syntax and Semantics (EISS) 11*.

Yang, Charles D. 2000a. Internal and external forces in language change. *Language Variation and Change*. 12 (03). 231-250.

Yang, Charles D. 2000b. *Knowledge and Learning in Natural Language*: MIT Ph.D. Dissertation.

Yang, Charles D. 2002. *Knowledge and Learning in Natural Language*. New York: Oxford University Press.

Yang, Charles D. 2004. Universal Grammar, statistics or both? *Trends in Cognitive Sciences*. 8 (10). 451-456. DOI: http://dx.doi.org/10.1016/j.tics.2004.08.006.

Yatsushiro, Kazuko. 2008. German determiner presuppositions in first language acquisition. In Heather Jacob, Harvey Chan & Enkeleida Kapia (eds.), the *Proceedings of the 32nd annual Boston University Conference on Language Development (BUCLD32) supplements*.

Zhang, Ning. 1997. *Syntactic dependencies in Mandarin Chinese*. Toronto, Canada: University of Toronto dissertation.

Zhou, Peng, & Stephen Crain. 2011. Children's Knowledge of the Quantifier *dou* in Mandarin Chinese. *Journal of Psycholinguistic Research*. 40 (3). 155-176. DOI: 10.1007/s10936-010-9161-z.