Proceedings of the 22nd North American Conference on Chinese Linguistics (NACCL-22) & the 18th International Conference on Chinese Linguistics (IACL-18). 2010. Vol 1. Clemens, L.E. & C.-M. L. Liu, eds. Harvard University, Cambridge, MA. 187-202.

Disjunction and Conditional in Child Mandarin

Yi (Esther) Su and Stephen Crain
Macquarie University

This study investigates 3-5-year-old Mandarin-speaking children's interpretation of disjunction word *huozhe* 'or' in *ruguo*-conditional sentences. Specifically, we assessed children's knowledge of a semantic principle conforming to first order logic, namely that disjunction licenses a conjunctive entailment when it appears in the antecedent clause of a conditional, but not in the consequent clause. The results reveal young children's mastery of this semantic principle in Mandarin Chinese. In particular, children demonstrated adult-like knowledge of the different truth conditions of disjunction in the two clauses of conditional sentences. Together with previous psycholinguistic findings (Crain 2008), the data suggest that the interpretation of logical words in child language sometimes conforms to classical logic. This, in turn, provides further evidence for logical nativism (Crain & Khlentzos 2008, 2010), according to which children draw upon an innate knowledge of logical expressions such as disjunction and conditional at the initial stage of language acquisition.

1. Introduction

Logical connectives such as *and, or, so, because,* and *if* can be used to express logical relationships, upon which formal principles of reasoning and logical systems are based. Over the past four decades, children's knowledge of these connectives has attracted considerate attention from scholars interested in the logical competence and development of the human mind (see e.g. Piaget 1969, Johnson-Laird & Byrne 2002, Braine & Rumain 1983 among others). It is widely believed, however, young children's initial interpretations of these expressions are not based on their logical counterparts (see e.g. Beilin & Lust 1975, Emerson 1980, French & Nelson 1985, Johansson & Sjölin 1975, Johnson-Laird & Byrne 2002, Morris 2008, Neimark & Slotnick 1970, Paris 1973, Piaget 1969, Taplin et al., 1974 among others). The classic Piagetian framework claims that logical competence requires a formal-operational structure that is not available until early adolescence (Inhelder & Piaget 1958). Some psychologists propose that children at different developmental stages adopt different mental models for individual connectives, where formal logical mechanisms play no role (Johnson-Laird 2001). Several psycholinguists advocate an input-based account of connective acquisition, which claims that children's initial uses of a connective, primarily reflecting the parental input, are limited to non-logical functions (Morris 2008, Quine 1992). Meanwhile, these arguments,

all supposing a disconnect between formal logic and reasoning in child language, have been bolstered by empirical findings from the developmental literature, much of which reports children's limited and late competence of the logical connectives (Beilin & Lust 1975, Braine & Rumain 1983, Emerson 1980, Johansson & Sjölin 1975, Neimark & Slotnick 1970, Paris 1973). Even in a few studies in which children demonstrate logical competence, their knowledge of logical connectives is generally not considered to be related to the truth conditions of propositional calculus (Braine & Rumain 1981, French & Nelson 1985).

Despite the widespread belief to the contrary, some recent research has resurrected the idea that humans are endowed with an innate logical faculty that is closely related to classical logic. On this account, logical notions structure thoughts and assist in the acquisition of language. This account can be called 'logical nativism' (Crain & Khlentzos 2008, 2010). According to logical nativism, at least some expressions in human languages, including sentential connectives by words like 'and' and 'or' and quantificational devices like 'every' and 'some', mirror the corresponding expressions in classical logic (Chierchia & McConnell-Ginet 2000, Crain 2008, Montague 1973). Moreover, logical nativists contend that the machinery for generating logical truths of these linguistic expressions is innately specified as part of the human biological blueprint (Chomsky 1988, Crain & Pietroski 2001, Fodor 1980, Macnamara 1986). Specifically, the semantic knowledge of these logical expressions is part of Universal Grammar (Crain et al. 2000). Given that Universal Grammar provides the truth conditions for these logical words, language learners are expected to know the truth conditions associated with these words as soon as they learn to map the linguistic expressions onto their corresponding logical operators. For example, in classical logic, the conjunction operator '&' is associated with the truth conditions, according to which a statement of the form 'p & q' is true if only p and q are both true. It follows that the task of the child exposed to English is to figure out that the English word *and* maps onto the corresponding conjunction operator '*&*' in the logical form; the task of a child exposed to Mandarin is to figure out that the Mandarin word *he* maps onto '*&*', and the task for Japanese-speaking children is to figure out that the Japanese word *mo* maps onto '*&*'. Therefore, the view of logical nativism leads to the expectations that (a) all languages will access the same semantic representations of logical expressions and (b) young children learning any human language will 'know' the truth conditions of its logical words as soon as these words enter their speech (Crain & Khlentzos 2008, 2010).

The present study was designed to obtain empirical data that would be relevant to the unabated debate of the logical versus non-logical nature of linguistic connectives in child language. In particular, we evaluate whether the meanings of disjunction and conditional in child language conform to the meanings of corresponding expressions in classical logic, by assessing children's interpretation of disjunction in conditional sentences. Although arguably simpler structures have been investigated in previous developmental literature, which mainly focus on individual connectives (e.g. see Braine

& Rumain 1983 for a review), few studies have evaluated children's knowledge of the interaction of both disjunction and conditional. We selected these complex linguistic structures because the truth conditions of disjunction in conditional statements are guided by a semantic principle conforming to first order logic, which has never been investigated in previous research. So, a careful exploration of children's interpretation of these two logical operators, whether or not adhering to the logical concepts, promises to deepen our understanding about the role classical logic plays in child language. Another innovation of the present study is to investigate children speaking Mandarin Chinese. The majority of the prior child studies on logical connectives have been focusing on just a few languages, mainly with English-speaking children. In the present study, we propose to broaden the empirical basis in the acquisition of logical words by assessing 3-5-year-old children speaking Mandarin Chinese. The research questions we address are two-fold. Firstly, we ask whether Mandarin-speaking young children interpret disjunction in conditional statements in ways that follow classical logic. If so, our second question concerns how children come to the knowledge of these connectives from the perspective of language acquisition.

2. Theoretical Background: Disjunction in Conditional Statements

One way to evaluate the role classical logic plays in the acquisition process of logical words, as adopted in this study, is to test whether some logical principles involving these connectives are presupposed in human languages, and belong as such to the linguistic competence of every human being, including children. In this section, we will firstly introduce the interpretation of disjunction in logic and in human languages. On this basis, we will propose a semantic principle conforming to classical logic, which guides the interpretation of disjunction in conditional sentences.

In first order logic, disjunction has the truth conditions associated with inclusive-*or*, such that a statement of the form *A v B* is true (i) if A is true but not B, (ii) if B is true but not A, and (iii) if both A and B are true. A statement of the form *A v B* is false, therefore, only if both A and B are false. It follows that the negated form ¬(A v B) logically entails (¬ A ∧ ¬B), as captured by one of de Morgan's laws of propositional logic in schema (1) (see e.g. Partee et al. 1990). According to this one of de Morgan's laws, disjunction generates a 'conjunctive entailment' when it appears in the scope of negation.

(1) $\neg (A \vee B) \Rightarrow \neg A \wedge \neg B$

This instantiation of de Morgan's laws is validated in many human languages, including English. As illustrated in the English sentence *Mary didn't see that John bought cake or ice-cream*, when disjunction word *or* appears in the scope of negation, it entails both (a) Mary didn't see that John bought cake and (b) Mary didn't see that John bought

ice-cream. Therefore, the conjunction of these statements is entailed by the original statement with *or*.

The parallels between formal logic and human languages run much deeper in that the conjunctive entailment of disjunction extends well beyond the case of negation, to a host of natural language expressions which are referred to as 'downward entailing' expressions (see e.g. Horn 1989, Ladusaw 1979). By definition, downward entailing contexts license inferences from general terms to more specific terms (i.e. from sets to their subsets). Example (2) shows that the antecedent of a conditional statement is downward entailing, validating inferences from set-referring term 'cake' to subset-referring term 'chocolate cake' [1]. By contrast, as illustrated in example (3), the consequent clause is not downward entailing and does not validate such inferences. So, the two clauses of conditional statements form a minimal pair, with respect to the semantic property of downward entailment.

(2) If a boy bought cake, then he got a plate.
$\Rightarrow$ If a boy bought chocolate cake, then he got a plate.

(3) If a boy got a plate, then he bought cake.
*$\Rightarrow$ If a boy got a plate, then he bought chocolate cake.

As one of the diagnostic properties of downward entailing context, disjunction generates a conjunctive entailment, when it appears in the scope of a downward entailing expression (see e.g. Crain 2008). The general schema for the conjunctive entailment of disjunction in the scope of a downward entailing operator Δ is illustrated in (4).

(4) Δ (A or B) $\Rightarrow \Delta$ A and Δ B

[1] We will restrict the discussion of conditionals, in the present paper, to those that keep the contexts constant for the inferences because this type of conditionals are the ones that are generally acknowledged as downward entailing and these are also the ones we investigate in the experimental studies. However, as noted by Heim (1984), several cases of conditional inferences with inconsistent contexts might have 'limited' downward monotonicity, especially in the inference pattern known as 'strengthening the antecedent'. For example, it is problematic to infer from (i) *If you go to Spain you will have a good time* to (ii) *If you go to Spain and have a car accident you will have a good time*, although the situations where *one goes to Spain and has a car accident* is a subset of situations where *one goes to Spain.* To avoid such invalid inferences, it is important to observe a pragmatic principle, i.e. when language users consider an inference, they do not switch implicit components of the context at random in the middle of the argument, but rather keep the context constant (e.g. the implicit contexts of (i) would be restricted to cases where you go to Spain without any accidents). It is generally agreed, therefore, so long as one keeps the contexts of the inferences constant, the downward entailingness of the antecedent can be maintained (Heim 1984, Kadmon & Landmon 1993, cf. von Fintel 1999).

If we apply the general schema in (4) to a conditional statement, the expectation is that disjunction will license a conjunctive entailment when it appears in the antecedent clause, which is downward entailing. This is confirmed in the English example (5).

(5) If a boy bought cake ***or*** ice-cream, then he got a plate.
⇒ if a boy bought cake, then he got a plate **and**
if a boy bought ice-cream, then he got a plate

Disjunction does not generate the conjunctive entailments, however, outside the scope of a downward entailing expression. For example, when disjunction appears in the consequent clause, a non-downward entailing context, it no longer generates a conjunctive entailment, as indicated by the '*' in (6). Instead, sentence (6) means if a boy got a plate, then he ordered (i) cake but not ice-cream, or (ii) ice-cream but not cake, or (iii) both cake and ice-cream. Since these are the truth conditions associated with disjunction in classical logic (i.e. inclusive-*or*), we call these the disjunctive truth conditions of disjunction in non-downward entailing linguistic contexts[2].

(6) If a boy got a plate, then he ordered cake ***or*** ice-cream.
*⇒ if a boy got a plate, then he ordered cake and
if a boy got a plate, then he ordered ice-cream

It is not just a fact about English that the two clauses of conditional sentences yield different truth conditions of disjunction. Other languages observe the same linguistic phenomenon. Take Mandarin for example, as with English *if*-conditional statements, the antecedent clause of the corresponding Mandarin *ruguo*-conditional statement is downward entailing. By contrast, the consequent clause is not downward entailing. Evidence for this conclusion is presented in examples (7) and (8), respectively.

(7) Ruguo xiaonanhai mai-le dangao, ta jiu na-le diezi.
if boy buy-ASP cake he then get-ASP plate
'If a boy bought a cake, then he got a plate.'

[2] However, a pragmatic implicature of exclusivity often reduces this range of truth conditions, by excluding circumstances in which both disjuncts are true (Horn 1972). The implicature arises because the expression or forms a scale with the expression 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 that is consistent with their state of knowledge, so if a speaker uses the weaker statement *or*, hearers infer that the speaker was not in a position to use the stronger statement *and*, so the hearer infers the negation of the stronger statement, i.e. *not (A and B)*.

⇒ Ruguo xiaonanhai mai-le qiaokeli dangao, ta jiu na-le diezi.
if boy buy-ASP chocolate cake he then get-ASP plate
'If a boy bought a chocolate cake, then he got a plate.'

(8) Ruguo xiaonanhai na-le diezi, ta jiu mai-le dangao.
if boy get-ASP plate he then buy-ASP cake
'If a boy got a plate, then he bought a cake.'
*⇒ Ruguo xiaonanhai na-le diezi, ta jiu mai-le qiaokeli dangao.
if boy get-ASP plate he then buy-ASP chocolate cake
'If a boy got a plate, then he bought a chocolate cake.'

Likewise, the same pattern of different truth conditions of disjunction is manifested in the antecedent versus the consequent in Mandarin *ruguo*-conditionals. Example (9) shows that the Mandarin disjunction word *huozhe* generates a conjunctive entailment in the antecedent clause of a *ruguo*-conditional. In contrast, disjunction licenses the full range of truth conditions associated with inclusive-*or* in the consequent clause, as illustrated in (10).

(9) Ruguo xiaonanhai mai-le dangao huozhe bingjiling, ta jiu na-le diezi.
if boy buy-ASP cake or ice-cream he then get-ASP plate
'If a boy bought cake or ice-cream, then he got a plate.'=conjunctive

(10) Ruguo xiaonanhai na-le diezi, ta jiu mai-le dangao huozhe bingjiling.
if boy get-ASP plate he then buy-ASP cake or ice-cream
'If a boy got a plate, then he bought cake or ice-cream.'=disjunctive

The different truth conditions of disjunction in the antecedent versus the consequent of conditional statements in English and in Mandarin are summarized in schema (11):

(11) If/Ruguo $_{ANT}$[...or/huozhe…], then/jiu $_{CONS}$[…….....]= Conjunctive
If/Ruguo $_{ANT}$[……...], then/jiu $_{CONS}$[…or/huozhe…]= Disjunctive
(ANT: antecedent; CONS: consequent)

From the perspective of first order logic, it is no accident that natural language disjunction should generate a conjunctive entailment in the antecedent of a conditional, but not in the consequent clause. This is because in first order logic, the truth condition of a conditional $p \rightarrow q$ 'if p, then q' is logically equivalent to the truth condition of the form $\neg p \vee q$ 'either not p, or q (or both)'. It follows that when disjunction appears in the antecedent versus the consequent of a conditional, it would be expected to demonstrate different truth conditions. To be specific, when disjunction appears in the antecedent *p*, it

resides within the scope of a negation operator ¬. Consequently, the appearance of disjunction in the antecedent is subject to one of the de Morgan's laws in (1), which generates the conjunctive entailment of disjunction. By contrast, when disjunction appears in the consequent *q*, it is not in the scope of negation and the de Morgan's law doesn't apply under this situation. As a consequence, the conjunctive entailment of disjunction is not generated in the consequent. So, the different behaviors of disjunction in the antecedent versus the consequent of conditionals are accounted for, in classical logic, by whether this one of de Morgan's laws applies in these two contexts.

To recap, in view of this cross-linguistic generalization in the interpretation of disjunction in conditional sentences, which conforms to first order logic, we derive the following semantic principle, as in (12):

(12) Disjunction licenses a conjunctive entailment when it appears in the antecedent clause of a conditional, but not in the consequent clause.

The present study was designed to assess whether young Mandarin-speaking children observe this semantic principle governing the interpretation of disjunction in conditional statements. To our knowledge, there have been no studies directly evaluating children's knowledge of the different truth conditions of disjunction in the two clauses of conditional sentences, in any language. Our experimental investigation therefore attempts to explore this uncharted territory in the acquisition studies on logical words.

3. The Experiment

This section presents a detailed description of our experiment on Mandarin-speaking children's interpretation of the disjunction word *huozhe* in the two clauses of *ruguo*-conditionals. More precisely, we ask the following questions: Do children generate the conjunctive entailment, when *huozhe* appears in the antecedent? Do they access the disjunctive truth conditions of *huozhe,* when it appears in the consequent?

3.1. Subjects

The subjects consisted of forty-one 3-5-year-old monolingual Mandarin-speaking children. The children ranged in age from 3; 11-5; 05, with a mean age of 4; 11. The children were recruited from Blue Sky Kindergarten of the Kaifu District in Changsha, China. In addition, 15 adult native Mandarin speakers served as a control group. These subjects are all Chinese students at Macquarie University in Sydney, Australia.

3.2. Method and Procedures

The experiment adopted the prediction mode of the Truth Value Judgment task (Chierchia et al. 1998). Specifically, 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. 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 (here 'Rabbit in hat') who watches the stories alongside the child. In the middle of the story, the puppet produces a sentence which purports to predict what will happen next. Then, the story continues and the puppet repeats her prediction after the outcome is revealed. The child's task is to judge whether or not the puppet's prediction is 'right or wrong' (i.e. true or false), based on the final outcome. When a child indicates that the puppet's prediction was 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 was introduced to the task with one story including four warm-up sentences. Two of these warm-ups were designed to elicit 'Yes' answers and the other two were designed to elicit 'No' answers. If children answered all these warm-up sentences correctly, and produced appropriate justifications for their 'No' responses, they were invited to participate in the main test sessions. Otherwise, children were eliminated from further testing. Two children said 'Yes' to false warm-up sentences and did not participate further. The other 39 children participated in the two main sessions of the experiment.

The 15 adults in the control group were tested only by the main experimenter, who told the stories and played the role of the puppet. Unlike the child subjects, adults only participated in one combined session with the target sentences (i.e. the filler sentences, control sentences and 'warm-up' trials were deleted). These adult subjects were also instructed to indicate whether the puppet was right or wrong, following each of the target assertions by writing down their answers. As with child subjects, whenever the adult subjects judged the puppet to be wrong, they were required to give justifications.

3.3. Materials

The experiment adopted a within-subject design in which each child subject was tested using similar non-linguistic contexts for test sentences with both downward entailing contexts (i.e. *huozhe* in the antecedent clause) and non-downward entailing contexts (i.e. *huozhe* in the consequent clause). For both testing sessions, the child subjects were each presented with four test trials. The first two test sentences contained *huozhe* in the antecedent clause, and the remaining two contained *huozhe* in the consequent clause. The stories were designed to make the test sentences false if *huozhe* appeared in the antecedent, but true if it appeared in the consequent. This was accomplished by satisfying one of the disjunctive truth conditions associated with disjunction, but not the truth conditions corresponding to the conjunctive entailment of disjunction. To illustrate, here is one of the two stories in which *huozhe* appeared in the antecedent.

> This story is about five ponies that helped a duck to move food to his new house. The duck said to the ponies, 'I need to move these sausages, corns and cake to my new house. Could you please help me?' The ponies agreed to help. The youngest pony with least strength moved the small cake. Two older ponies moved two sausages. Two biggest and strongest ponies moved two heavy corns. The duck says, 'Well done! I should reward you for your generous help.' He brought out a lot of prizes, which included four gold coins, four shells, a pink star and a flower ball. Now, how would the duck reward the ponies?

At this point, the puppet first predicted with a filler sentence *ruguo xiaoma yunzou dangao, ta jiu hui dedao zhuzi* (English: *If a pony moves a cake, then he will get a marble*). Then the story continued and the pony that moved the cake received a pink star, rather than a marble. After the child made a judgment about the filler sentence (which is false in this trial but true in the other antecedent trial), the puppet predicted about the prizes the other ponies would get, by using the test sentence in (13):

(13) Ruguo xiaoma yunzou yumi huozhe huotuichang, ta jiu hui dedao jingbi.
if pony move corn or sausage he then will get gold coin
'If a pony moves a corn or a sausage, then he will get a gold coin.'

What really happened next was that the two ponies that moved corns got gold coins and the two ponies that moved sausages got shells, instead of gold coins. Figure 1 illustrates the final outcome.

Figure 1: The Pony Story

This test sentence receives a different truth value depending on whether or not children assign the conjunctive entailment to *huozhe*. If children know that the antecedent of a conditional is downward entailing, they would be expected to generate the conjunctive entailment of disjunction and, consequently, they should reject the test

sentence on the grounds that the two ponies that moved sausages got a shell. On the contrary, if children fail to generate a conjunctive entailment, then they should accept (13), since the sentence would mean that if a pony moves a corn, then he will get a gold coin or if a pony moves a sausage, then he will get a gold coin. This reading makes the test sentence true in the context because the ponies that moved corns got gold coins. Another possibility is that they would also say 'Yes' out of uncertainty, if they don't understand these complicated test sentences. So, if children do not generate the conjunctive entailment, they are expected to accept the test sentence.[3]

The remaining two test stories assessed whether or not children allowed the disjunctive truth conditions of disjunction when it appears in the consequent of conditional statements. To illustrate, here is a typical story.

> This story is about one dog, one peacock and four rabbits, who went to Minney's home to play a game called 'finding jewels'. The dog was the first to try because he had a sensitive nose. However, this game was pretty hard and he couldn't find any jewels. Minney, in order to encourage her friends to carry on, prepared different kinds of prizes to reward those jewel-finders, which include six balls, six butterflies and six stars. The game continued and finally Minney's friends all found jewels. Minney said, 'Good job! Now I will reward you with some prizes.'

At this point, the puppet first predicted the prize that the dog could get by using the filler sentence *ruguo xiaogou zhaodao baoshi, ta jiuhui dedao xiaoqiu* (English: If the dog finds a jewel, then he will get a ball), which was true because Minney later gave a ball to the dog. Then the puppet predicted what the peacock could get by using another filler sentence *ruguo kongque zhaodao baoshi, ta jiuhui dedao hudie* (English: If the peacock finds a jewel, then she will get a butterfly), which was false because Minney later gave a star to the peacock. So, these two filler sentences were expected to evoke a 'YES' and a 'NO' response respectively from children. After the child subjects judged the truth or falsity of the filler sentences, the puppet made a prediction about what the other four rabbits could get by uttering the test sentence in (14).

(14) Ruguo xiaotuzi zhaodao baoshi, ta jiu hui dedao xiaoqiu huozhe xingxing
if rabbit find jewel she then will get ball or star
'If a rabbit finds a jewel, then she will get a ball or a star.'

What happened later was that Minney rewarded two rabbits with balls and she rewarded the other two rabbits with stars. The puppet repeated her prediction after the

[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.

final outcome was revealed, as in Figure 2. Notice that the story ended with every rabbit possessing one of the two objects mentioned in the test sentence, but no rabbit possessed both objects.

Figure 2: The Rabbit Story

The test sentence (14) is true if children assign disjunctive truth conditions to *huozhe*, i.e. *if a rabbit finds a jewel, then she will get either a ball or a star*. However, if children are not aware that the consequent is non-downward entailing, they could reject sentence (14). This could happen, for example, if children analyzed both the antecedent and the consequent of a conditional statement to be downward-entailing, thereby licensing a conjunctive entailment of disjunction in both positions. If so, children's interpretation of (14) would require every rabbit who found a jewel to have received both a ball and a star, contrary to fact.

In addition to the four test sentences, there were two control sentences (one true and one false) in each session. In a typical 'False' control trial, four frogs picked flowers and one frog picked a feather for Tiger. The puppet predicted about the prizes those frogs would receive by using the control sentence *Ruguo xiaoqingwa zhaidao xiaohua, ta jiu hui dedao zibeike* (English: If a frog picks a flower, then she will get a purple shell). Finally, two of the four frogs that had picked flowers received purple shells and the other two got butterflies. So the control sentences, though structured similarly as the filler sentences, were presented with multiple characters in scenarios similar to the test trials. These control trials were included to ensure that children could process conditional sentences without disjunction in complicated testing scenarios.

Children who failed to respond correctly to the control sentences or to the filler sentences were excluded from further analysis. All subjects answered correctly to the filler sentences. But nine subjects who wrongly accepted false control sentences were excluded from further data analysis. This left 30 children between the ages of 3; 11 and 5; 11, with a mean age of 4; 11.

3.4. Results

In this experiment, we asked whether children master the different truth conditions of disjunction in the two clauses of the Mandarin *ruguo*-conditionals. If so, children would reject the test sentences when disjunction appeared in the antecedent clause. Moreover, they would accept test sentences when disjunction appeared in the consequent clause. The results confirmed this hypothesis. When disjunction was in the antecedent, the children only said 'Yes' to the test sentences 3% of the time (4/120). By contrast, when *huozhe* was in the consequent of conditionals, children replied with 'Yes' 90% of the time (108/120). Moreover, children justified their negative judgments of the test sentences for the right reasons. For example, 20 children consistently justified their replies with 'no' to (13) by pointing out that the two ponies the moved sausages got shells, not gold coins. The other 10 children typically commented that it was right that the two ponies that moved corns did receive gold coins, but it was wrong that the two ponies that moved sausages got shells. The control group of 15 Mandarin-speaking adults correctly rejected the test sentences with disjunction in the antecedent 93% of the time (56/60), and they all accepted the test sentences with disjunction in the consequent (60/60).

4. Discussion

The purpose of this study was to assess the role formal logic plays in child language, in particular whether children interpret natural language connectives in adherence to their logical concepts. We begin our discussion by summarizing the findings. This study investigates 3-5-year-old Mandarin-speaking children's knowledge of a semantic principle conforming to first order logic: disjunction licenses a conjunctive entailment in the antecedent of a conditional statement, but not in the consequent. The experimental findings clearly demonstrate that Mandarin-speaking children observe this semantic principle at the early stage of language development. Specifically, the 3-5-year-old Mandarin-speaking children we tested demonstrated understanding that *huozhe* generates a conjunctive entailment when it appears in the antecedent of conditionals, but they refrain from doing so in the consequent clause, by assigning the disjunctive truth conditions to *huozhe*.

Therefore, contrary to several prior developmental studies that address children's illogical interpretation of connectives (see e.g. Beilin & Lust 1975, Emerson 1980, French & Nelson 1985, Johansson & Sjölin 1975, Johnson-Laird & Byrne 2002, Morris 2008, Neimark & Slotnick 1970, Paris 1973, Piaget 1969, Taplin et al. 1974 among others), our findings are consistent with the hypothesis of logical nativism, according to which classical logic and human language, including child language, are built on a common foundation. First of all, young Mandarin-speaking children in our study adhere to the semantic principle governing the interpretation of disjunction in conditional statements, by assigning correct truth conditions to these logical words. Secondly, the data seem to suggest that the meanings of several linguistic expressions in human languages, including logical connectives like disjunction and conditional, conform to the

meanings of the corresponding expressions in classical logic. To be specific, together with previous psycholinguistic studies (Boster & Crain 1993, Crain et al. 2002, Goro & Akiba 2004, Gualmini & Crain 2002, Gualmini et al. 2003, Jing et al. 2005, Notley et al. 2010, Su & Crain 2009), our data provide further evidence that young children have implicit knowledge of the fact that disjunction is inclusive-*or*, as in classical logic. This conclusion is based on the observation that young children across languages license the conjunctive entailments of disjunction, when it appears in the scope of a variety of downward entailing expression (Crain 2008). Meanwhile, children's knowledge of the semantics of disjunction, in turn, sheds insights into their knowledge of the conditional statements. In particular, children's competence of the different truth conditions of disjunction in the two clauses of conditionals suggests, indirectly, that children decompose a conditional into an antecedent clause and a consequent clause, as in first order logic. Moreover, children understand the different properties of these two clauses, such that only the antecedent, a downward entailing context, generates the conjunctive entailment of disjunction, but not the non-downward entailing consequent clause.

The critical issue is how children obtain the knowledge that these linguistic expressions correspond to their logical counterparts at the early stage of language development. In view of the complexity of these logical structures, it is unlikely that young children learn the meanings of these logical words from relevant evidence in the input. Exacerbating the problem of learnability is the fact that in learning the interpretation of disjunction in conditional statements, what children learn is not the distribution of disjunction, but its interpretive properties. More precisely, what children learn is that disjunction is assigned different truth conditions, when the same word appears in different places of conditionals. So, even given most optimistic assumptions of children's capacity to draw on generalizations based on distributional cues, they would easily fail in capture the different truth conditions of disjunction in the two clauses of conditionals. By contrast, these problems of learnability seem to be solved on the account of logical nativism. According to logical nativism, children across languages are endowed with innate logical concepts about the meanings of logical expressions (Crain & Khlentzos 2008, 2010). Therefore, despite the lack of evidence in their experience, children can effortlessly 'cognize' these seemingly complicated structures, by simply drawing upon innate principles guiding the interpretations of these logical words.

The study reported in the present paper demonstrates, for the first time, that Mandarin-speaking children adhere to the semantic principle governing the interpretation of disjunction in conditional statements. Further studies need to be conducted to investigate whether children speaking other languages understand the same complicated logical structures. The fact that different languages adhere to the same logical principles is circumstantial evidence that human language users draw upon an innate set of logical primitives that are used in speaking and in reasoning. Therefore, if it is discovered that young children, across languages, observe the same logical principles and adopt a semantics for logical expressions in human languages which parallels the semantics of

the corresponding expressions in first order logic, then this would add further evidence for the argument of logical nativism.

References

Beilin, Harry, and Lust, Barbara. 1975. A study of the development of logical and linguistics connectives: linguistics data. In Studies in the Cognitive Basis of Language Development, ed. by Harry Beilin, 217-284. New York: Academic Press.

Boster, Carole T., and Crain, Stephen. 1993. On children's understanding of *every* and *or*. In Proceedings of Early Cognition and the Transition to Language, ed. by Carlota Smith, 1-23. Austin: University of Texas.

Braine, Martin D. S., and Rumain, Barbara. 1981. Development of comprehension of 'or': Evidence for a sequence of competencies. Journal of Experimental Child Psychology 31. 46-70.

Braine, Martin D. S., and Rumain, Barbara. 1983. Logical reasoning. In Handbook of Child Psychology: vol. 3. Cognitive Development, ed. by J. Flavell & E. Markman. New York: Academic Press.

Chierchia, Gennaro, Crain, Stephen, Gausti, Maria Teresa, and Thornton, Rosalind. 1998. 'Some' and 'or': A study on the emergence of logical form. In Proceedings of the 22nd Boston University Conference on Language Development, eds. by Annabel Greenhill, Mary Hughes, Heather Littlefield and Hugh Walsh, 97-108. Somerville, MA: Cascadilla Press.

Chierchia, Gennaro, and McConnell-Ginet, Sally. 2000. Meaning and Grammar: An Introduction to Semantics. Cambridge, MA: MIT Press.

Chomsky, Norm. 1988. Language and the Problems of Knowledge: The Managua lectures. Cambridge, MA: MIT Press.

Crain, Stephen, Gualmini, Andrea, and Meroni, Luisa. 2000. The acquisition of logical words. Logos and Language: Journal of General Linguistics and Language Theory 1. 49-59.

Crain, Stephen, and Pietroski, Paul. 2001. Nature, nurture and Universal Grammar. Linguistics and Philosophy 24.139-185.

Crain, Stephen, Gardner, Amanda, Gualmini, Andrea, and Rabbin, Beth. 2002. Children's command of negation. In Proceedings of the 3rd Tokyo Conference on Psycholinguistics, ed. by Yukio Otsu, 71-95. Tokyo: Hituzi Publishing Company.

Crain, Stephen. 2008. The interpretation of disjunction in Universal Grammar. Language and Speech 51.1-19.

Crain, Stephen, and Khlentzos, Drew. 2008. Is logic innate? Biolinguistics 2. 24-56.

Crain, Stephen, and Khlentzos, Drew. 2010. The logic instinct. Mind and Language 25. 30-65.

Emerson, Harriet F. 1980. Children's judgments of correct and reversed sentences with 'if'. Journal of Child Language 7.137-155.

von Fintel, Kai. 1999. NPI-licensing, Strawson-entailment, and context-dependency. Journal of Semantics 16. 97-148.

Fodor, Jerry A. 1980. Fixation of belief and concept acquisition. In Language and learning: The debate between Jean Piaget and Noam Chomsky, ed. by M. Piattelli-Palmarini. Cambridge, MA: Harvard University Press.

French, Lucia A., and Nelson, Katherine. 1985. Young children's knowledge of relational terms: Some *if*s, *or*s, and *but*s. New York: Springer-Verlag.

Goro, Takuya, and Akiba, Sachie. 2004. The acquisition of disjunction and positive polarity in Japanese. In Proceedings of the 23rd West Coast Conference on Formal Linguistics, 251-264. Summerville, MA: Cascadilla Press.

Gualmini, Andrea, and Crain, Stephen. 2002. Why no child or adult must learn de Morgan's laws. In Proceedings of the 26th Annual Boston University Conference on Language Development, eds. by Barbora Skarabela, Sarah Fish and Anna H.-J. Do, 243-254. Somerville MA: Cascadilla Press.

Gualmini, Andrea, Meroni, Luisa, and Crain, Stephen. 2003. An asymmetric universal in child language. In Proceedings of Sinn und Bedeutung VI, ed. by Matthias Weisgerber, 136-148. Konstanz, Germany: Fachbereich Sprachwissenschaft der Universitat Konstanz.

Grice, H. Paul (1975). Logic and conversation. In Cole, P. & J. L. Morgan (eds.) Syntax and Semantics, Volume 3: Speech Acts. New York: Academic Press. 41-58.

Heim, Irene. 1984. A note on negative polarity and downward entailingness. NELS 14: 98-107.

Horn, Laurence. 1972. On the semantic properties of logical operators in English, University of California at Los Angeles: Doctoral dissertation.

Horn, Laurence. 1989. A natural history of negation. Stanford, CA: CSLI Publications.

Inhelder, Barbel, and Piaget, Jean. 1958. The growth of logical thinking from childhood to adolescence. New York: Basic Books.

Jing, Chunyuan, Crain, Stephen, and Hsu, Ching-Fen. 2005. The interpretation of focus in Chinese: Child vs. adult language. In Proceedings of the 6th Tokyo Conference on Psycholinguistics, ed. by Yukio Otsu, 165-190. Tokyo: Hituzi Publishing Company.

Johansson, B. S., and Sjölin, Barbro. 1975. Preschool children's understanding of the coordinates 'and' and 'or'. Journal of Experimental Child Psychology 19. 233-240.

Johnson-Laird, Philip N. 2001. Mental models and deduction. Trends in Cognitive Science 5. 434-442.

Johnson-Laird, Philip N., and Byrne, Ruth M. J. 2002. Conditionals: A theory of meaning, pragmatics, and inference. Psychological Review 109. 646-678.

Kadmon, Nirit and Landman, Fred. 1993. Any. Linguistics and Philosophy 16. 353-422.

Ladusaw, William. 1979. Negative polarity as inherent scope relations, University of Texas: Doctoral dissertation.

Macnamara, John. 1986. A Border Dispute: The Place of Logic in Psychology. Cambridge, MA: MIT Press.

Montague, Richard. 1973. The proper treatment of quantification in ordinary English. In Approaches to Natural Language, eds. by K. J. J. Hintikka, J. M. E. Moravcsik and P. Suppes. Dordrecht, the Netherlands: Reidel.

Morris, Bradley J. 2008. Logically speaking: evidence for item-based acquisition of the connectives AND & OR. Journal of Cognition and Development 9. 67-88.

Neimark, E. D., and Slotnick, N. S. 1970. Development of the understanding of logical connectives. Journal of Experimental Child Psychology 61. 451-460.

Notley, Anna, Zhou, Peng, Jensen, Britta, and Crain, Stephen. 2010. Children's interpretation of *before* and *or* in English and Mandarin Chinese. In Proceedings of GLOW in ASIA VII, eds. by Rajat Mohanty and Mythili Menon, 97-116. Hyderabad, India: EFL University Press.

Paris, Scott G. 1973. Comprehension of language connectives and propositional logical relationships. Journal of Experimental Child Psychology 16. 278-291.

Partee, Barbara H., Meulen, Alice ter, and Wall, Robert E. 1990. Mathematical methods in linguistics. Dordrecht, Boston: Kluwer Academic Publishers.

Piaget, Jean. 1969. The mechanisms of perception. London: Rutledge & Kegan Paul.

Quine, Willard Van Orman. 1992. Pursuit of Truth. Cambridge, MA: Harvard University Press.

Su, Yi (Esther), and Crain, Stephen. 2009. Disjunction and universal quantification in child Mandarin. In Proceedings of the 10th Tokyo Conference on Psycholinguistics, ed. by Yukio Otsu, 265-289. Tokyo: Hituzi Syobo Publishing.

Taplin, John E., Staudenmayer, Herman, and Taddonio, Judith L. 1974. Developmental changes in conditional reasoning: Linguistic or logical? Journal of Experimental Child Psychology 17. 360-373.