The acquisition of logical connectives: a cross-linguistic perspective

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Logical connectives

• Negation: English *not*, Mandarin *meiyou*
• Disjunction: English *or*, Mandarin *huozhe*
• Conjunction: English *and*, Mandarin *he*
Disjunction across languages

(1) *John didn’t bring beer or wine to the party.*

a) John didn’t bring beer to the party
   AND

b) John didn’t bring wine to the party
Disjunction in classical logic

Conjunctive interpretation of disjunction under negation:

In classical logic, \( \neg (A \lor B) \Rightarrow \neg A \land \neg B \)

\( \lor \): inclusive-or, \( \land \): conjunction, \( \neg \): negation, \( \Rightarrow \): entailment

English conforms to classical logic
(1) John didn’t bring beer or wine to the party.

a) John didn’t bring beer to the party
   AND
b) John didn’t bring wine to the party
It is either beer or wine that John didn’t bring to the party.

The Mandarin disjunction word *huozhe* fails to generate a conjunctive entailment in the scope of negation.
Conjunction across languages

(3) John didn’t bring both beer and wine to the party.

a) John didn’t bring beer to the party
   OR
b) John didn’t bring wine to the party
In classical logic, \( \neg (A \land B) \Rightarrow \neg A \lor \neg B \)

English conforms to classical logic
The Mandarin conjunction word is *he*. Negated conjunctions are interpreted as meaning ‘neither’ - regardless of word order:

(4) Yuehan *meiyou* dai *pijiu* *he* *hongjiu* qu *juhui*.  
John not bring beer and wine go party  
‘John didn't bring beer and wine to the party.’

(5) Yuehan *pijiu* *he* *hongjiu* *dou meiyou* dai qu *juhui*.  
John beer and wine both not bring go party  
’John didn’t bring both beer and wine to the party.’

Meaning: As for beer and wine, John didn’t bring them to the party.
Cross-linguistic differences

• Following Goro (2004, 2007), words for conjunction and disjunction are interpreted as positive polarity items (+PPI) in some languages but not in others (-PPI) (cf. Szabolcsi 2002).

• In Mandarin both the disjunction word *huozhe* ‘or’ and the conjunction word *he* ‘and’ are +PPI, whereas in English both are -PPI.
The disjunction parameter

- Mandarin: \( \text{OR} = +\text{PPI} \)
- English: \( \text{OR} = -\text{PPI} \)

The value with disjunction taking scope over negation is \( \text{OR} = +\text{PPI} \)

The value with negation taking scope over disjunction is \( \text{OR} = -\text{PPI} \)
The disjunction parameter

- Mandarin disjunction is +PPI

Mandarin

pijiu huozhe hongjiu Yuehan meiyou dai pijiuhuozhehongjiu qu juhui.
The disjunction parameter: Mandarin

Negated disjunctions fail to generate a conjunctive entailment.

(2) Yuehan meiyou dai piju huozhe hongjiu qu juhui.
   John not bring beer or wine go party
   ‘It is either beer or wine that John didn’t bring to the party.’
The disjunction parameter

- English disjunction is -PPI

**English**

John didn’t bring *beer or wine* to the party.
The disjunction parameter: English

- Negated disjunctions license a ‘conjunctive’ entailment, as in classical logic.

(1) John didn’t bring beer or wine to the party.

\[ \neg(A \lor B) \Rightarrow \neg A \land \neg B \]
The conjunction parameter

- Mandarin: AND = +PPI
- English: AND = -PPI

The parameter value with conjunction taking scope over negation is AND = +PPI.
The value where negation takes scope over conjunction is AND = -PPI.
The conjunction parameter: Mandarin

**Mandarin**  AND = +PPI

*pijiu he hongjiu* Yuehan *meiyou* dai *pijiu he hongjiu* qu jiuhui.
John didn’t bring both beer and wine to the party.
Research questions

• How do Mandarin-speaking children and English-speaking children understand sentences containing these logical connectives?

Sentences containing negation and disjunction
Sentences containing negation and conjunction
Learnability problem

• Learnability problems could potentially arise, when one value of a parameter makes a sentence true in a subset of the circumstances that make the sentence true on the other value of the parameter (Crain et al., 1994).
The disjunction parameter

- Mandarin disjunction is +PPI
- English disjunction is -PPI

Mandarin

pijiu huozhe hongjiu Yuehan meiyou dai piji huozhe hongjiu qu juhui.

English

John didn’t bring beer or wine to the party.
The disjunction parameter

English setting: NOT > OR
  (e.g., John brought neither)

Mandarin setting: OR > NOT
  (e.g., It is either beer or wine that John didn’t bring)

Subset (English) - Superset (Mandarin)
Learnability problem

• If English-speaking children start off with the superset reading, the majority of the input they hear would be consistent with that reading, because adults would always use the sentence in a situation where the subset reading is true, and whenever the subset reading is true, the superset reading is also true.

• How will children revert to the subset reading from their initial superset reading? They have to record the fact that adults do not use the sentence in circumstances where the superset reading is true, but the subset reading is false.

• Observing and mentally recording what does not happen is likely to be beyond the cognitive capacities of most adults, much less children.
Semantic Subset Principle (SSP)

Children initially favor the interpretation that makes the sentence true in the narrowest range of circumstances. The initial setting is the value that generates the subset reading (Crain et al., 1994; Notley et al., 2012).

Children will encounter positive evidence to override their initial parameter setting, if these values are not exhibited by adult speakers of the local language.
• For *disjunction*, the ‘subset’ reading is OR = -PPI, as in English.

• For *conjunction*, the ‘subset’ reading is AND = +PPI, as in Mandarin.
According to the SSP, Mandarin-speaking children are expected to initially favour the OR = -PPI value of the disjunction parameter, as in English.

For Mandarin-speaking children, this interpretation is presumably not attested in the input, because adult speakers favour the OR = +PPI value of the parameter.
• **English-speaking children** are expected to initially favour the AND = +PPI value of the Conjunction Parameter, as in **Mandarin**.

• For English-speaking children, this interpretation is presumably not attested in the input, because adult speakers favour the AND = -PPI value of the parameter.
Experiments: Truth Value Judgement Task

- Short vignettes were acted out in front of the child and Kermit the Frog. The vignettes were about different animals who were asked, in turn, if they were happy to eat cake, a carrot and a green pepper.
  - If an animal ate both, it received a gold medal
  - If it ate only one, it received a blue medal
  - If it ate neither one, it received a black cross

- With the vegetables removed, Kermit attempted to guess what each animal had eaten, based on the medal it received. On the critical trials, the animal was wearing a blue medal (i.e., it had only eaten one vegetable), follow the protocols used by Goro and Akiba (2004).
Experimenter: Look! These animals going to play an “eating-game”!!
Experimenter: Here’s a piece of cake, a green pepper, and a carrot. All the animals love cake, but they don’t like vegetables. So here’s the rule of the game: if an animal eats not only the cake but also the vegetables, he gets a better prize.
Experimenter: For example, if someone eats cake, and the pepper, and also the carrot…then he gets a gold medal!
Experimenter: If someone eats cake, and either one of the vegetables, but not both…then he gets a blue medal.
Experimenter: If someone eats only cake, but none of the vegetables, then he gets a black cross…
Experimenter: Now, here comes a pig. He will play the game.
Experimenter: The pig first picked up the cake. He loves cake and of course he ate it!
Experimenter: Then he picked up the pepper. He doesn’t like peppers...but he managed to eat it all up!
Experimenter: Then he picked up the carrot...Oh no, he couldn't eat the carrot!
Experimenter: So, the pig ate the cake, and he ate the pepper, but he didn’t eat the carrot. Which prize does he get?

Child: A blue medal!
Experimenter: Yes, a blue medal!
Experimenter: Now here comes another animal…
- the “eating-game” continues with 12 animals. Every one eats the cake. 4 eat both vegetables, 4 eat only one vegetable, and 4 eat neither
After the eating game, Kermit tries to remember what each character ate:
Kermit: Ok, now I’m going to tell you how well the animals did. Umm, the pig … I don’t remember what he ate…oh, but, he has a blue medal!
Kermit: I know. *Test sentence is produced.*
Negated disjunctions
The Disjunction Parameter: Mandarin

- Mandarin disjunction is +PPI for adults, but -PPI for children

**Adult Mandarin**

*pijìu huózhe hóngjiù* Yuehan *meiyou* dai *pijìu huózhe hóngjiù* qu jìuhui.

**Child Mandarin**

Yuehan *meiyou* dai *pijìu huózhe hóngjiù* qu jìuhui.
Kermit: *Xiaozhu meiyou chi huluobo huozhe qingjiao*
(The pig didn’t eat the carrot or the pepper)
Results

- Twenty Mandarin-speaking children (mean age 4;5) rejected the target ‘not … or’ statements 97% of the time. By contrast, Mandarin-speaking adults accepted them 95% of the time.

- To justify their rejections of Kermit’s statements, children pointed out the animals in question had only eaten one vegetable (hence the blue medal). Children assigned the ‘neither’ reading, as in English.
Summary: Disjunction Parameter

Xiaozhu *meiyou* chi *huluobo* *huozhe* *qingjiao*. ‘The pig didn’t eat the carrot *or* the pepper’

- Mandarin-speaking adults consistently *accepted* the test sentences
- Mandarin-speaking children consistently *rejected* them, as did English-speaking children and adults

**Conclusion**: Mandarin-speaking children adopted the English setting of the Disjunction Parameter (-PPI)
Negated conjunctions
The Conjunction Parameter: English

- English conjunction is +PPI for children, and -PPI for adults

Adult English

John didn’t bring *both beer and wine* to the party.

Child English

*both beer and wine* John didn’t bring *both beer and wine* to the party.
Kermit: I know. *The pig didn’t eat both the pepper and the carrot*
Results

- In response to negated conjunctions, 21 English-speaking children (mean age 4;9) rejected the target ‘not… both… and’ statements 95% of the time

- English-speaking adults accepted the same statements 72% of the time

- English-speaking children justified their rejections of Kermit’s statements, by pointing out that the animals in question had only eaten one vegetable. Children assigned the ‘neither’ reading, as in Mandarin.
Summary: Conjunction Parameter

The pig didn’t eat both the carrot and the pepper.

- Adult speakers of English consistently accepted the test sentences

- English-speaking children consistently rejected them, as did Mandarin-speaking children and adults

Conclusion: English-speaking children adopted the Mandarin setting of the Conjunction Parameter (+PPI)
Parameter Setting: The SSP

- **The Disjunction Parameter**: Mandarin-speaking children initially adopt the English parameter setting.

- **The Conjunction Parameter**: English-speaking children initially adopt the Mandarin parameter setting.

- Children initially adopt the ‘strongest’ reading, regardless of the value of the parameter favored by adults. The results are consistent with the Semantic Subset Principle.
“All principles and constructs of universal grammar are available at the outset and all child grammars will be ‘possible human grammars’, in the sense of falling within the patterns of adult grammars (either observed or permitted under the theory). The child’s grammar may, however, deviate from that of the language he will ultimately acquire.”

(Goodluck 1991)

“Child language can differ from the language of adults in the same linguistic community, but only in ways that adult languages can differ from each other.”

(Crain 1990)
<table>
<thead>
<tr>
<th></th>
<th>Mandarin</th>
<th>English</th>
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</thead>
<tbody>
<tr>
<td><strong>Conjunction</strong></td>
<td>+PPI (<em>he</em>)</td>
<td>-PPI (<em>and</em>)</td>
</tr>
<tr>
<td><strong>Disjunction</strong></td>
<td>+PPI (<em>huozhe</em>)</td>
<td>-PPI (<em>or</em>)</td>
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Language Universals

- Linguistic structures where all adult and child grammars conform to the laws of classical logic

- Language universals are revealed when polarity sensitivity is cancelled
A Well-studied PPI: English *some*

- English *some* takes scope over negation at logical form.

\[ \text{Julia didn’t eat some of the kangaroo.} \]

\[ \text{some of the kangaroo Julia didn’t eat some of the kangaroo} \]

\[ \text{Julia didn’t eat any of the kangaroo} \]
Focus Operators

- **Polarity Sensitivity is cancelled** when a PPI appears in the predicate phrase of a **focus operator**

**Only** Julia ate **some** of the kangaroo

**Only** Julia ate **any** of the kangaroo

**some** and **any** are equivalent in meaning
Focus Operators

Focus operators introduce covert negation in the entailment.

Only Julia ate *some* of the kangaroo.

- **Presupposition**: Julia ate *some* of the kangaroo
- **Entailment**: Everyone else did *n’t eat some* (= *any*) …

In the entailment, *some* is in the scope of *negation*.
Disjunction and Focus

Zhiyou Yuehan dai-le pijiu huozhe hongjiu qu juhui.
only John bring-ASP beer or wine go party
‘Only John brought beer or wine to the party.’

(a) Presupposition:
Yuehan dai-le pijiu huozhe hongjiu qu juhui.
John bring-ASP beer or wine go party
‘John brought beer or wine to the party.’

(b) Entailment:
Qita-ren meiyou dai pijiu huozhe hongjiu qu juhui.
other-people not bring beer or wine go party
‘Everyone else didn’t bring beer or wine to the party.’

Everyone else didn’t bring beer AND everyone else didn’t bring wine.

In the entailment, disjunction is in the scope of negation.
Conjunction and Focus

Zhiyou Yuehan dai-le pijiu he hongjiu qu juhui.
only John bring-ASP beer and wine go party
‘Only John brought beer and wine to the party.’

(a) Presupposition:
Yuehan dai-le pijiu he hongjiu qu juhui.
John bring-ASP beer and wine go party
‘John brought beer and wine to the party.’

(b) Entailment:
Qita-ren meiyou dai pijiu he hongjiu qu juhui.
other-people not bring beer and wine go party
‘Everyone else didn’t bring beer and wine to the party.’

→ Everybody else didn’t bring beer OR everybody else didn’t bring wine.

In the entailment, conjunction is in the scope of negation
Language Universals

When polarity sensitivity is cancelled, all languages conform to the laws of classical logic

Disjunction: \( \neg (A \lor B) \Rightarrow \neg A \land \neg B \)

Conjunction: \( \neg (A \land B) \Rightarrow \neg A \lor \neg B \)
Predictions

Across languages, there will be no differences between adults and children in the interpretation of conjunction and disjunction in sentences with focus operators:

*Only* John brought beer **or** wine to the party.
*Only* John brought both beer **and** wine to the party.
Conjunction and Focus in Child English and Mandarin

Participants

• 18 monolingual English-speaking children (mean age 4;3, range 3;5 to 5;1), 20 monolingual Mandarin-speaking children (mean age 4;7, range 4;5 to 4;10)

• 13 English-speaking adults and 20 Mandarin-speaking adults
Procedures

Truth Value Judgment Task (Crain & Thornton, 1998)

Here is what happened.

Is Kermit right or wrong?
English:
Only Mickey Mouse chose both a box and a rabbit.

Mandarin:
Zhiyou Milaoshu xuan-le hezi he tuzi
only Mickey Mouse choose-ASP box and rabbit
‘Only Mickey Mouse chose a box and a rabbit.’

Presupposition: Mickey chose both a box and a rabbit.
Entailment: Everyone else didn’t choose a box and a rabbit.
Only Mickey Mouse chose both a box and a rabbit.
Only Mickey Mouse chose both a box and a rabbit.

Acceptance rates:
- Mandarin-speaking adults: 90%
- Mandarin-speaking children: 90%
- English-speaking adults: 100%
- English-speaking children: 90%
Only Rabbit played both a whistle and a bell.
Adult-false Scenario

Only Rabbit played both a whistle and a bell.

Rejection rates:
- Mandarin-speaking adults: 100%
- Mandarin-speaking children: 70%
- English-speaking adults: 100%
- English-speaking children: 90%
Conjunction and Focus in Child English and Mandarin

• Both English and Mandarin Chinese, including child language, adhere to the laws of classical logic once the polarity sensitivity of conjunction is cancelled by focus operators

\[ \neg (A \land B) \Rightarrow \neg A \lor \neg B \]
Disjunction and Focus in Child English and Mandarin

English:
Only Bunny Rabbit ate a carrot or a pepper.

Mandarin:
Zhiyou Tuzi chi-le huluobo huozhe qingjiao.
‘Only Bunny Rabbit ate a carrot or a pepper.’

Presupposition: Bunny Rabbit ate a carrot or a pepper.
Entailment: Everyone else didn’t eat a carrot or a pepper.
Only Bunny Rabbit ate a carrot or a pepper.
Only Bunny Rabbit ate a carrot or a pepper.

Acceptance rates:
- Mandarin-speaking adults: 100%
- Mandarin-speaking children: 100%
- English-speaking adults: 100%
- English-speaking children: 93%
Adult-false Scenario

Only Bunny Rabbit ate a carrot or a pepper.
Adult-false Scenario

Only Bunny Rabbit ate a carrot or a pepper.

Rejection rates:
Mandarin-speaking adults: 100%
Mandarin-speaking children: 70%
English-speaking adults: 100%
English-speaking children: 90%
Both English and Mandarin Chinese, including child language, adhere to the laws of classical logic once the polarity sensitivity of disjunction is cancelled by focus operators

$$\neg (A \lor B) \Rightarrow \neg A \land \neg B$$
Summary

- Children and adults exhibited similar patterns in the interpretation of conjunction and disjunction in sentences with focus operators.

- Focus operators successfully cancelled the polarity sensitivity of conjunction and disjunction words in child language, and thereby permit us to witness the logical meanings that children assign to these expressions.
Conclusions

• Across languages, conjunction words and disjunction words are subject to parametric variation. These words are PPIs in some languages, but not in others.

• Children initially favour parameter values that make sentences true in the narrowest range of circumstances. This ensures that there will be positive evidence if the local language favours the alternative parameter value.
Conclusions

• When polarity sensitivity is cancelled, both children and adults interpret **disjunction** and **conjunction** as in classical logic, yielding two putative linguistic universals.

• Human languages draw upon an innate logic faculty which is consistent with classical logic in important respects.
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