“The Kindergarten-path Effect: Studying Sentence Processing in Young Children”

0. Introduction

- How do children process language in real time?
- Do they coordinate multiple sources of information during interpretation?

Initial research: adults don’t take into account discourse/pragmatics principles in choosing a parse in temporary syntactic ambiguities.

Recent research: adults do take into account more than just syntax.
- Processing is rapid and context-sensitive.
- Adults make initial mistakes that they later revise.

“Garden-path phenomenon.”- listeners make a choice to go down one path when they encounter an ambiguity; if wrong, they later retrace their steps and go back to the intended interpretation.
- What kinds of information take priority?

Consider these sentences:
1. Anne hit the thief with the stick.
2. Anne hit the thief with the wart.

- Adults use lexically specific syntactic information, semantic plausibility, frequency of lexical co-occurrence, and referential context.
- They use statistical regularities pertaining to syntax, not broad structural heuristics.
- They coordinate the linguistic properties with information from the context.

Constraint-based lexical theory- assumes a constraint-satisfaction approach to ambiguity resolution.
- Multiple sources of information can be used to converge on one interpretation.

Referential Principle- context can affect processing commitments, especially when lexical properties of the stimulus are relatively neutral.

1. Children’s On-line Language Processing Abilities

- How do children process the PP-attachment ambiguity?
- Do they use the Referential Principle?
- The ability to figure out meanings of anaphoric (ie something that refers back) elements well mastered in all age groups, but developmental differences were observed for pronouns.
- 5 year olds rely more on pragmatic plausibility than lexical factors (such as gender-marking) in their assignment of pronominal co-reference.

Children have knowledge of contextual factors associated with the Referential Principle, so it can, in principle, play a role in the understanding of restrictive relative clauses. (contra some studies)

Experiment 1: The Frog(s), chick, Napkins, and Box Experiment

Figure 1: The 1-Referent context

Figure 2: The 2-Referent context
Some terminology

Referents: things in the world that expressions point to. Here - possible objects to be moved
  1-Referent context: one frog, one chick
  2-Referent context: two frogs, one on a napkin, one not.

Target: intended referent. Here - the frog on the napkin, the correct one to move
  Incorrect/Other: the frog on the table or the chick, the wrong animal to move
  Incorrect Destination: the empty napkin

Ambiguous Phrase: “Put the frog on the napkin in the box.”
Non-ambiguous Phrase: “Put the frog that is on the napkin in the box.”

Modifier: expression interpreted as modifying another. Here - one that tells you which frog to move
  NP Attachment: interpreted as “modifier” – expression which is a sister of the noun “frog”

Destination: expression interpreted as the goal of movement. Here - one that tells you where to put a frog
  VP Attachment: interpreted as “destination” – expression which is a sister of the verb “put”

Course Grain Data: what the subjects picked, where they put it, etc.
Fine Grain Data: where their eyes looked, for how long, when, etc.
Cross Checking: comparing Course Grain conclusions with Fine Grain conclusions

Onset Phoneme: first sound of the words, especially the relevant ones, like frog vs. horse

What happened - [http://www.ircs.upenn.edu/Trueswellabs/video.html]
- Adults used the Referential Preference; they considered the empty napkin only when the sentence was
  Ambiguous and it was a 1-Referent trial.
- Children looked at the empty napkin for 1 & 2 referent Ambiguous trials.
  Data showed an effect of ambiguity, and no interaction between ambiguity and context.
So: the children didn’t use the Referential Principle, but rather had a bias for the destination interpretation.
They were often unable to recover from their initial mistake

Observations:
  ● 1-Referent trial mistakes almost always had the correct animal, but incorrect destination
  ● 2-Referent trials had almost an equal number of correct animals moved as incorrect animals moved.
  ● Children adopt a single strategy (structural or interpretive) for dealing with ambiguity.

“Course Grain Data”
  ● Five year olds prefer the Destination interpretation.
  ● Subjects usually directed gaze at incorrect destination during ambiguous trials, regardless of context.
  ● Subjects were at chance levels when selecting Target over Other animal in 2-referent trials,
    suggesting that “on the napkin” was not treated as a Modifier and therefore was uninformative in
    determining a possible referent.

“Fine Grain Data”
  ● Children looked more at the Incorrect Destination about 300 ms after the onset of the word
    “napkin,” mostly under the Ambiguous conditions.
  ● This occurs in both 1-Referent and 2-Referent trials - insensitivity to the Referential Principle?
  ● Ambiguity had an effect, context did not, and the two factors didn’t interact.

Cross checking with Course Grain analysis: 91.1% of the time, the two analyses agreed.

Recognition of Direct Object Noun “Frog” (and Referential Ambiguity)
  ● The 1-Referent conditions showed a divergence between fixations on the Target and Other animals,
    with the higher probability on the Target, telling us the correct referent was established soon after
    disambiguating phonemic material was perceived.
  ● All 1-Referent contexts: onset phoneme different for the Target and Other animal (frog vs. chick.)
  ● For 2-Referent Unambiguous contexts, similar divergence between fixations on Target vs Other was
    delayed until the onset of the word “napkin,” when fixations on the Target would increase.
Statistics
1. Prior to any phonemic information to discriminate between the two animals, there were no significant differences in looking times to the Target and Other animals.
2. Upon hearing “frog” and before hearing “napkin” more time was spent looking at the Target animal in the 1-referent context, but not the 2-referent context.
3. After hearing “napkin” subjects fixated more on the Target in all conditions except the 2-Referent Ambiguous one. SO: ‘on the napkin” was taken as a Modifier in the 2-Referent Unambiguous condition, distinguishing the Target from the Other. It was NOT taken as a Modifier just because of 2-Referent context, resulting in continued competition between the two possible referents.

Summary of the Fine Grain Analyses
- Children’s 1st interpretation of the ambiguous “on the napkin” = Destination rather than Modifier.
- Children’s assignment of interpretation (correct or otherwise) is highly incremental.
- Referential competition between the Target and the Other animals was consistently resolved at the points in speech where phonemic info could help: at “frog” in the 1-Referent conditions, and at “napkin” in the 2-Referent Unambiguous condition.
- The 2-Referent Ambiguous condition showed no resolution, suggesting the inability to take the ambiguous phrase “on the napkin” as a Modifier.

Eye Movements for Correct and Incorrect Trials
- Subjects were choosing the referent based on which animal they happened to look at first.

Experiment 2: Adults
- Adults experienced a “garden path” in for the Ambiguous 1-Referent trials.
- There were increased looks to the Incorrect Destination for those trials only.
- Interaction between context and ambiguity.

Fine Grain Analysis
- Increased looks to Incorrect Destination occur shortly after the onset of the word “napkin,” restricted to the 1-Referent Ambiguous trials, implying an initial Destination interpretation.
- Sensitivity to the Referential Principle is essentially immediate.
- Ambiguity and Context interact.
- Disambiguation occurs just after the onset of the word “frog” in the 1-Referent Contexts.
- Looks to the Target are greater in the 1-Referent Unambiguous than the 1-Referent Ambiguous trials, because subjects are inspecting the Incorrect Destination in the latter but not the former.
- The 2-Referent Contexts showed more consideration of the Other.
  - Divergence was early, especially in the 2-Referent conditions, showing that subjects were using the preposition “on” as a clue.

Statistics:
- Before the word “frog,” there was no difference between looking at the Target or Other, in any run.
- Between “frog” and “napkin,” the subjects looked more at frogs.
- “On” helped, but not reliably.
- After “napkin,” subjects looked more at the Target in all conditions.

This tells us...
The Modifier interpretation was pursued in both Ambiguous and Non-Ambiguous conditions, distinguishing the Target from the Other.

Comparison with 5 Year Olds
- There was a reliable triple interaction between Context, Ambiguity and Age.
- Adults were affected by Context and Ambiguity, Children only by Ambiguity.
- Both groups showed rapid incremental interpretation.
● They differed in how they handled temporary syntactic ambiguity.
  o Adults resolved it with the Referential Principle, 5 year olds did not.
  o Adults chose the Modifier in 2-Reference contexts, children always preferred the Destination.
  o Adults chose Destination when the context indicated that the Modifier was unnecessary (1-Referent context.)
● Adults recovered from incorrect interpretations, children did not.
  o Adults had very few errors.
  o Children’s choice of referent in 2-Referent Ambiguous trials was random.

Explanations for VP Attachment Preference for the Younger Group

Explanation 1: Children parse according to some principle, such as “choose the simplest structure.” Maybe as people age, revising their Minimal Attachment parsing commitment (based on lexical and context factors) becomes faster.

Explanation 2: Input matters. Children may be using syntactic/semantic knowledge of verbs and possible arguments. This makes the Destination option more likely because “put the frog on the napkin” is the most likely syntactic alternative based on adults’ speech to children.

Young children exhibit strong sensitivity to lexically specific syntactic preferences.

Wiggle Frog Experiment

2-referent context. Lexically specific syntactic biases play a role in children’s processing commitments, but there must be other constraints leading to a preference for the Destination interpretation.

Ininsensitivity to the Referential Principle in the Youngest Parsers

● Verb specific syntactic and semantic properties present in the stimuli so strongly supported the Destination interpretation that referential factors were unable to impact processing preferences.
● It’s possible that children have the Referential Principle, but can’t use it in certain circumstances.

Summary and Closing Marks

● Five year olds have a language processing system that relies more heavily on local linguistic factors to inform parsing preferences, along with a general inability to reverse commitments to initial interpretations. They have a highly incremental processing system. Word recognition and referential resolution in syntactically unambiguous environments appears to proceed smoothly, showing patterns similar to adults.
● Adults can use relevant contextual factors to inform parsing commitments, and they can revise.

On Not Being Led Down the Kindergarten Path

This is a reply to Trueswell, Sekerina, Hill, and Logrip 1999.
Argues against the conclusion that children, unlike adults, lack sensitivity to referential contexts in comprehension in certain circumstances and do not possess the same linguistic cognitive mechanisms as adults.
Meroni and Crain contend that:
  ● Performance systems of children and adults differ only minimally
  ● Children are sensitive to referential context
  ● Children make use of contextual factors to resolve structural ambiguities in on-line (real time) sentence interpretation
They also say that the referential context in which sentences are presented plays an immediate role in their interpretation, such that referential features of the context mitigate, and often eliminate, so-called “garden path effects”.

Subtraction Method: A research strategy that manipulates features of the experimental design and the referential context so that the children’s and adults’ responses are not out of step with each other.
The aspects of the experiment that are manipulated need to have been proven to lessen children’s difficulties in dealing with linguistic structures through previous research. By eliminating children’s errors, we see the ways in which children’s systems are the same as those of adults. We also see the impediments to their correct performance in certain experimental conditions.

Using this method, reexamine “Put the frog on the napkin into the box”.

**Two modifications** in the experimental design eliminate children’s errors.

1. change context
2. modification in experimental procedure so that it facilitates children’s planning and execution of correct actions (children act out verbal instructions in the order presented, instead of conceptually correct order, so this method of subtraction reveals their competence).

- According to Meroni and Crain, adults use algorithms to make a plan after hearing instructions. Then, they use various cognitive acts to execute it.
  - Use computer programming language: **compile mode** (generate a complete plan, then begin to carry it out) and **interpret mode** (start to plan and act while the instructions are still being uttered)

- Children are less automated because they have less verbal working memory capacity.

- Through subtraction, manipulate children’s responses to get them to use compile mode. How? Withhold experimental display until child has listened to whole sentence (phrase-and-then-display condition). Forces them to mentally devise a plan. Experiment’s results provide evidence for this.

- Maintains the **Continuity Assumption**: In language, children access the same cognitive mechanisms as adults do.

Previous research states that in the absence of context, parsers choose VP over NP. Why?

**Their explanation**: a parsing principle that instructs the parser to immediately discharge the theta roles associated with the verb (Theta Assignment Principle or TAP).

The verb ‘put’ assigns two internal theta roles, a Theme (NP) and Destination (PP).

Parser discharges the Theme role to the initial NP ‘the frog’ and the Destination role to the first PP ‘on the napkin’. Hence - a garden path effect at the 2nd PP ‘into the box’ = the ‘true’ Destination

- In certain referential contexts, TAP induces the garden path effect:
  - **1-referent context**: evokes a garden path effect at 2nd PP ‘into the box’. Evidence that initial PP has been initially misattached (high) in accordance with TAP.
  - In other referential contexts, **no garden path**:
  - **2-referent context**: two frogs = early application of TAP, interprets PP ‘on the napkin’ as Destination, but which frog? Parser takes another track; interprets PP ‘on the napkin’ as modifier of NP.

Follows **Principle of Referential Success (PRS)** – parser favors linguistic structures that succeed in referring to entities in the domain of discourse over ones that do not.

PRS is thought to override TAP according to Referential Theory, so garden path effects in 2-Referent are completely eliminated.

PP ‘on the napkin’ is immediately interpreted as modifier of NP because there is more than one frog and neither one is more salient than the other.

- Trueswell et al. results: adult findings consistent with Referential Theory.
- Children: **different results**. Did not recover from garden path effect in 1-Referent context and also experienced garden path effects in 2-Referent. Made 3 kinds of errors:
  1. ignored content of PP #2
  2. **hopping error**: moved frog not on napkin onto empty napkin and then into box
  3. **double action error**: moved frog not on napkin onto empty napkin, then moved frog originally on napkin into box. 

-
A closer look at the data

M&C’s Observations:

1. Consistent pattern in 2-Referent context: picked up the “wrong” frog 90% of the time.
   If guessed randomly, should have been 50%.
   Inferred wrong frog, so possibly adhered to Principle of Referential Success. Why?
   - PRS must be satisfied if one frog is more salient than other.
2. Children should also be credited with Theta Assignment Principle. Why?
   - Found unique referent for NP ‘the frog’, immediately discharged the Destination role to PP ‘on the napkin’

This explains their non-adult actions.

Trueswell et al.: children resort to guessing in 2-Referent (right sequence for wrong reasons).

Meroni and Crain disagree. Indirect evidence, based on eye-movement patterns. Movement patterns for adults and children may just be different because children’s planning isn’t as automated.

Other Research

Examples from previous research of interpret mode in sentences with a restrictive relative clause.

Hamburger and Crain (1982; 1984; 1987)

Consider the two sentences:
(2) The dog pushed the cow that jumped over the sheep.
(3) The dog pushed the cow and jumped over the sheep.

Design: 4-6 year olds given a dog, cow, and sheep toy. Told to act out sentence told to them.

For (2), most children made the dog push the cow and then jump over the sheep.
   Inappropriate for (2) but appropriate for sentences like (3), which are conjoined clauses.

Led some researchers to conclude that children assigned a “conjoined clause analysis” to sentences with relative clauses.

- Adding additional cows into the study significantly reduced the children’s errors.
  The extra objects permitted the restrictive relative clause to serve its function
  (restricting from a set to a unique element of that set).
- In this design (with extra cows), sequence performance differed with age when “sheep” was replaced with “fence” in (2). Four-year-olds acted out the relative clause, whereas three-year-olds acted out the two clauses in an order-of-mention fashion, main clause first.

(AMidon and Carey 1972; Clark 1971)

Consider sentences (4) and (5)
(4) Pick up the helicopter after you pick up the car.
(5) After you pick up the car pick up the helicopter

Once again, yielded order-of-mention results.

Children who heard (4) made errors, but children who heard (5) executed the series correctly.

Changes in experimental design reduced children’s errors.
   Child had to express intent to pick up subordinate object, “helicopter” in (4), before sentence was uttered. Almost no error in this condition.

Conclusion: Errors before experiment modifications were due to order-of-mention phenomenon.
   Once modifications were made, they allowed to take entire sentence into account.

Final example: pre-nominal modifiers

“The second striped ball”

Figure 3

- Adults pointed to second striped ball, i.e. the third ball (counting from the left).
- Children (ages 4-6) pointed to the second ball, i.e. the first striped ball.
Just as in the other two studies, children chose the correct ball in a condition where the entire sentence was uttered before they were given an opportunity to act (phrase-and-then-display manipulation).

**Meroni and Crain’s Proposal:**
- Children’s errors in selecting the “wrong” frog in the Trueswell studies were the result of the interpret mode. They call this the **bird-in-the-hand problem**
  - Arises after hearing PP#2 ‘into the box.’
  - Child has already interpreted the command to mean “pick up the frog that is not on the napkin and put him on the empty napkin”; PP#2 is disambiguating and requires a plan for moving “other” frog (not the one child is holding).
  - Because frog in hand could not figure into a revised plan, child has 3 options for action, corresponding to the 3 types of errors reported.
    1) ignore PP#2 completely.
    2) interpret PP#2 as second destination for bird in hand (hopping error).
    3) finish current plan, then start again—compile mode (double action error).
- Children are expected to perform as well as adults in compile mode. They just prefer interpret mode.
- If experimental design is set up so that interpret mode is rendered inoperative, children will use compile mode, and results will be similar to adult group’s.

**A new experiment by Meroni and Crain**
- Similar design to Trueswell et al., but two differences: goals are to
  1) block the pragmatic inference that one frog was more highly salient than the other, and
  2) discourage the interpret mode and encourage the compile mode.

**How they inhibited the pragmatic inference:**
- Place both frogs on napkins, one red, one blue. There was also an empty napkin that was the same color as one of the other napkins (red).
  Test sentences were changed accordingly:
  (7) Put the frog on the red napkin into the box.
**How they discouraged interpret mode and encouraged compile mode:**
- Phrase-and-then-display design.
  Allowed children to formulate the plan without being biased by display and to prevent premature execution.
  Children introduced to characters, told a story, then told to turn around while listening to sentence, then to turn back around immediately after sentence ends to perform series of events in target sentence.
  Children age 3,09 to 5,09
  Four target trials interspersed with four fillers
  Prediction: children would be correct 90% of the time.
  Results: correct 93% of the time.

**Conclusion:** Children’s on-line analysis conforms to **Principle of Referential Success**, as long as they are prevented from immediately executing a response dictated by **Theta Assignment Principle**.

These findings are also consistent with **Referential Theory** and the **Continuity Assumption**.