

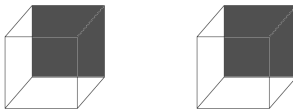
SECOND ORDER EMBEDDING AND SECOND ORDER FALSE BELIEF

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1. Introduction

The human cognitive system has the remarkable ability to organize streams of information in such a way that adding more often results in less. In the visual cognitive domain the Necker cube phenomenon is such an example. A single cube can be seen in two ways: the dark side as a front panel of the cube or as a panel in the back. Adding a similar cube should result in a four-way ambiguity: both dark panels in the front, the back or alternating. However, human beings have a really hard time seeing all four “readings”. We seem to see only two readings; either both cubes have the dark panel in front or in both have them in the back of the cube.

(1)



The focus of this paper is on recursive embedding, a similar phenomenon in language and belief contexts. The *that* in the small discourse in (2) can refer to a range of propositions. Some of them are given in (3). However *what Mary likes* in (4) is only the embedded proposition *John arrived early and brought a lovely cake for Christmas*.

(2) John arrived early, and he brought a lovely cake for Christmas.
Mary liked that.

- (3) a. John brought a lovely cake for Christmas
 - b. John arrived early and brought a lovely cake.
 - c. John arrived early.
 - d. a lovely cake for Christmas

- (4) Mary liked that John arrived early and brought a lovely cake for Christmas.

Hollebrandse and Roeper (submitted) proposed *The Principle of Propositional Exclusivity* to capture this. The core idea is that embedding organizes meaning by excluding (irrelevant) meanings. They argue that true recursiveness can only uniquely be seen at the multiple embedding level.

Recursive embedding, i.e., multiple embedding, is the core part of grammar. We believe that its role is bigger than that and extends to other cognitive domains. De Villiers (2005) showed a tight relation between linguistic embedding and embedding in belief contexts. She showed that learning to attribute beliefs to someone else in an adult way is driven by adult knowledge of linguistic embedding.

To explore this we designed a battery of experiments testing linguistic and cognitive embedding. This paper reports on the rationale behind that battery, most of the battery itself and some preliminary results.

2. Embedding - Recursion

Recursion is the cornerstone of grammar (Hauser, Chomsky and Fitch, 2002; Roeper, 2007). But what is recursion? Recursion, in its simplest form, is a function that takes itself. The effect is that it can create potentially infinite strings. In this section we focus on the fact that a single embedding is not the same as a multiple embedding. Hollebrandse and Roeper (submitted) argued that constructions showing multiple embedding can only be the product of (true) recursion. Single embedding can also be the result of a recursive rule system, but doesn't need to be.

The discourse in (5) has the same meaning as the sentence in (6), which shows that it is possible to convey an embedded meaning across a sentence boundary. At a single embedding level there is no unique role for complementation, i.e., a discourse (5) could convey the same meaning as a sentence with a complement clause (6).

- (5) The bridge is broken. John knows that.

(6) John knows that the bridge is broken.

The similarity between (5) and (6) breaks down when we extend the discourse in (5) with another “embedding” (7): (7) and (8) do not seem to have the same meaning. The *that* in (7) refers to (9) (Roeper, 2007).

(7) The bridge is broken. John knows that. His sister doesn’t think that.

(8) His sister doesn’t think that John knows the bridge is broken.

(9) His sister doesn’t think that the bridge is broken.

The exclusive role of embedding is uniquely visible in multiple embedding, because at a single, first-order embedding there are more options to embed. The embedding could have been created by a recursive system or by a non-recursive system. Syntactically this might be on a par with true complements and adjuncts.

Now we have established that there is a difference between first-order and second-order embedding, we can wonder whether this is a peculiarity of Germanic languages, since syntactic complementation is a frequently used form in those languages. Hollebrandse (2000) suggested, in trying to explain the lack of dependency between language embedding and first-order false belief in the acquisition of Japanese, that might be a preferred substitute for a first-order complement clause in Japanese (see also Matsuo and Hollebrandse, 1999).¹ He suggested that in acquiring first-order belief representations the discourse route is the alternative to complementation for languages such as Japanese.

Another language candidate for taking such an alternative route is Pirahã, described by Everett (2005) as a language that lacks recursive embedding completely. The Pirahã might have a form of first-order embedding² but lack second-order embedding completely. If this is true, it raises the question how Pirahã would report on second order belief contexts. It is conceivable that a discourse as in (7) can be interpreted as a

¹ Hollebrandse (2000) used Sequence of Tense as an embedding test, contrary to De Villiers (2005) who used a complementation. An alternative explanation for the Japanese finding could be found in cross-linguistic variation of Sequence of Tense. Embedded relative tenses in Japanese are not sensitive to clause boundaries as they are in English (Hollebrandse, 2005)

² This is probably closer to direct speech (Everett, 2005; Sakel and Stapert, submitted)

multiple embedded meaning. We will not address further the cross-linguistic issue³, but focus on the acquisition of multiple embedding.

The above raises an interesting question about language development: Do children show any restrictions on discourse? Children might acquire the organizing nature of recursive embedding quite late in their development, possibly out of lack of the appropriate syntactic-semantic structure. In the meantime they might resort to a non-recursive form of embedding. In the next section an experiment is presented that tests children (and adult) behavior on discourse embedding.

It is conceivable that comprehension of discourse embedding is enhanced by having cognitive templates derived from recursive propositions in language, which easily allow representation of these propositional dependencies. In other words, it ultimately is necessary to know how this kind of discourse represented knowledge is cognitively represented. It is at least logically possible that the cognitive representation is a version of grammatical embedding, given its efficiency.

3. Second-order Discourse

The question of whether children were able to construct a second-order reasoning on the basis of a discourse with main clauses with no embedded clauses was explored in an experiment described in this section.

Subjects listened to audio-taped stories of the type as in (10). The stories were followed by a yes/no question and a question of justification. Two versions were tested (11a) and (11b).

- (10) Jimmy and his sister live next to a bridge.
 The bridge is broken.
 Jimmy knows that.
 His sister doesn't think that.
- (11) a. Will his sister cross the bridge? Why?
 b. Will his sister warn Jimmy? Why?

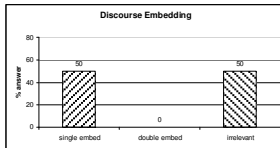
Version A focuses the subject on “the broken bridge” proposition. Subjects will answer *yes* on the basis of the first-order construal *His sister*

³ Hollebrandse is sponsored by the 6th Framework EU project *Characterizing Human Language by its Structural Complexity* which addresses this question, among other questions. Also the NSF grant *Epistemology and indexicality in English, Tibetan and Navajo* addresses it. De Villiers and Roeper are involved in this grant.

doesn't think that the bridge is broken and *no* on the second-order reasoning *His sister doesn't think that Jimmy knows that the bridge is broken, (but she knows that the bridge is broken)*. Version B focuses the subject on Jimmy's knowledge. Subjects will answer *yes* on the basis of the second-order construal *His sister doesn't know that Jimmy knows that the bridge is broken* and *no* on the basis of the first-order construal *His sister doesn't think that the bridge is broken*. The purpose of the why-question is to confirm the chosen construal. There were two training items and six test items.

Eighteen American-English children (6;3 – 6;11, avg: 6;9) were tested, as well as thirteen adults. The results of the 6 year-olds are given in the table in (12).

(12)



The results are dramatic: they show that the 6 year-olds do not allow any second-order construal, the double embedded meaning appears unattainable, even accidentally or by a strange “guesswork” which produces experimental noise in many experiments. The clarifications to the yes/no answers were either irrelevant or clearly first-order. Examples of irrelevant and first-order answers are given in (13a) and (13b) respectively.

- (13) a. (Will his sister warn Jimmy?) yes, because she is nice.
 b. (Will his sister cross the bridge?) no, because she doesn't know it is broken.

Second-order reasoning was not observed. Like the 6 year-olds, the adults did not give second-order construals, except for one adult who gave 4 (out of 6) second-order answers.

4. Verbal Second-Order False Belief

A verbal False Belief task was tested on 35 American-English children (6;1 – 7;10, avg: 6;11). The 18 children from the second-order

discourse experiment were included. The children were told stories and asked questions in between. One of the stories is given in (14).

(14) Bake Sale



Picture 1: Sam and Maria are playing together and look out the window and see that the church is having a bake sale.

Picture 2: Sam watches Maria grab her money and run out of the house and over to the church. “Ah ha,” Sam says. “She’s going to buy chocolate chip cookies, her favorite.” And then Sam goes back to playing with his toys.

Picture 3: On her way to the bake sale, Maria runs into the mailman and tells him, “I’m going to get a nice pumpkin pie for Grandma.”

a. Probe: Does Sam know that Maria is going to get a pumpkin pie?

Picture 4: When Maria gets to the bake sale, she finds out that all they have are brownies. So she couldn’t buy a pumpkin pie for her grandma, but buys a bunch of brownies to bring back to her family instead.

a. Probe: Does Sam know that she bought brownies?

b. 1st order FB: What did Maria think she was going to buy at the bake sale? Why?

Picture 5: Back at the house, Mom comes in and says to Sam “I noticed that the church is having a bake sale.” “Oh yes,” Sam says. “Maria went there.” Then Mom asks, “oh, what does Maria think they’re selling at the bake sale?”

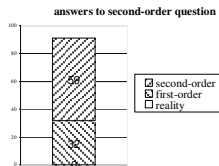
c. 2nd order FB: What does Sam tell his mom? Why does he tell her that?⁴

⁴ See also Sullivan, Zaitchik and Tager-Flusberg (1994) for using a second-order question in the form of a first-order embedding.

- b. 1st order FB: What did Maria think she was going to buy at the bake sale? Why?

Four items were tested. The results of the answers to the second-order question are given in (15).

(15)



Fifty-nine percent of the answers to the second-order question are adult-like. However, 32% of the answers reflect a first-order reasoning. None of the responses was based on reality. All children answered the first-order false belief questions correctly.

We can make two interesting observations about the responses to the why-question: First, second-order “failers” are fine in retelling the story. This indicates that they were competent in following the story. Moreover they only use single embedded clauses, and remarkably none of these children gives a multiple embedding. An example is given in (16). This could be seen as an indication that children do not have the complexity of second-order embedding in their language and therefore they cannot yet handle cognitive structure of that same complexity in an adult way. This is in contrast with second-order passers who often give explanations containing multiple embeddings (17).

- (16) “the boy thinks that its lollipops and the girl thinks that its chocolates because she actually put a chocolate bar in the bag”

Child102, age: 7;3

- (17) “because he thinks she thinks they are selling them”

Child105, age: 6;10

The stories are quite complex. There is a lot to keep track of. The purpose of the probe questions was to organize the information and keep children focused on the important details needed for the false belief questions. Moreover 17 children were asked a first-order question at the end of each trial. If complexity of the events was the only factor then answering a first- or a second-order question at the end could be equally

difficult. It turned out that children had no difficulty with answering the first-order question at the end.

The conclusion is that 6 – 7 year-olds can attribute second-order beliefs, but are far from ceiling in doing so. The next section presents an experiment exploring handling of second-order embeddings in language.

5. Second-Order Language Embedding

Parallel to the second-order belief embeddings of the previous section we tested second-order language embedding. Eighteen children (6;3 – 6;11, avg: 6;9)⁵ presented stories followed by questions (18). There were 6 items.

(18)



Dad is talking to Mom. Look outside! Dad tells Mom that Billy said that it's warm enough without a coat.

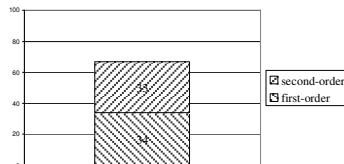
What did Dad tell Mom?

There were two potential answers in this experiment, corresponding with a first-order embedding (19a) and with a second-order one (19b).

- (19) a. (Dad said) Billy said it's warm enough without a coat
 b. (Dad said) it's warm enough without a coat

This set-up invites a double embedding, since it is pragmatically unlikely that fathers say that it is warm enough without a coat while it is snowing.

(20)



⁵ These 18 children were a subset of the 35 tested for second-order False Belief.

The results show that a third of the answers are second-order answers and a third are first-order answers. As in the False Belief trials, we see that children are able to give second-order answers, but are not at ceiling.

6. Conclusions and Discussion

We started with the observation that recursive embedding allowed an exclusive, logical relation among propositions, while discourse sequences allowed many possible readings. Thus recursive embedding represents connected propositions with efficiency and logical entailments not easily attainable with discourse circumlocutions.

The second starting point of this paper is De Villiers' Language First hypothesis which states that to acquire adult-like handling of reasoning about beliefs a child has to have acquired language of a certain embedding complexity. This was proven at a first-order level. We asked ourselves the question whether the same dependency would exist at a second-order level: Do children only get second order cognitive embedding once they have language of that complexity? At this point it is too early to answer this main question.

Our goal was then to start down both acquisition paths: when do children attain recursive embedding and how do they comprehend comparable concepts in discourse. The fact that children do poorly in both tasks suggests, perhaps, that mastering recursive embedding enables the creation of one cognitive representation onto which to project recursive discourse embedding. How these paths ultimately intersect in detail remains a research challenge.

The experimental data clearly show that second-order theory of mind is a different milestone than first-order theory of mind. We are convinced that there is a difference between first- and second-order embedding phenomena, both in language and cognition. The core of this must lie in the exclusive explicitness that a system of recursion provides, where discourse representations allow too many or too few represented connections to enable deductive reasoning.

Acknowledgments

Thanks to the children and their parents and teachers from the Smith College Campus School, Northampton, Massachusetts. Also thanks to the Smith College and UMass Amherst students that participated in the experiment. Our work was supported by a grant for international collaboration between the Universities of Groningen and Massachusetts

from NWO (Netherlands Organization for Scientific Research), “The acquisition of tense and aspect, wh-questions and quantification” (# 235-70-006, P.I. Angeliek van Hout). Hollebrandse was supported by the Characterizing Human Language by its Structural Complexity (CHLaSC) a EU 6th Framework Programme project (# 028395). De Villiers and Roeper were supported the NSF (National Science Foundation) grant, “Epistemology and indexicality in English, Tibetan and Navajo” to Margaret Speas (# 0527509). Thanks to the Acquisition Lab at University of Groningen in particular: Petra Hendriks, Angeliek van Hout and Erik-Jan Smits. Thanks to the Acquisition Lab group at UMass, Amherst in particular: Jay Garfield, Peggy Speas, Emily Sowalsky, and others working on different aspects of recursion.

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