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2 Indirect Recursion: The Importance of Second-Order Embedding and Its Implications for Cross-Linguistic Research

Bart Hollebrandse

1 The Relation between Subordinate Clauses and Belief Reports

The best way to report a belief is with a sentence with a subordinate clause embedded under a mental state verb such as *think*, *know*, or *believe*.¹ For example, the sentence in (1) is a perfect linguistic report of the thought balloon in (2a):

(1) Ernie thinks that it is raining.

(2) a.

b.

The structures in (2) share an interesting feature: both the cognitive structure (2a) and the linguistic structure (2b) involve a form of embedding. This similarity might be the reason why embedded structures, i.e., complement clauses, are the “best” way of expressing a belief. De Villiers (2005) even argues for an even closer relation between the two structures. She proposed the language-first hypothesis, i.e., it is the development of linguistic structure that triggers the development of cognitive belief structure.

However, the evidence for the tight relation between linguistic and cognitive structures comes exclusively from Indo-European languages (de Villiers and

¹ The author thanks Petra Hendriks, Angeliek van Hout, Marcus Maia, Andrew Nevins, Tom Roeper, Uli Sauerland, Jill de Villiers, and the audiences of the UMass Conference on Recursion, the Recursion in Human Languages conference in Normal, Illinois, and the TARK XIII workshop, Reasoning About Other Minds. This work was supported by the Netherlands Organisation for Scientific Research (NWO) under Grant number 277-70-005 and a EU 6th Framework Programme under Grant number 028395.

Pyers 2002; de Villiers 2005; Hollebrandse 2000). It is quite conceivable that languages from other language families express beliefs in different structures. Other languages might use constructions other than the complement clause. In this chapter, I will show how tight the relation between the two structures is, by presenting both empirical and experimental data. I will also suggest that the tight relation should hold for all languages in the world. It is also conceivable that other languages have very different complement constructions. This question is also addressed in several chapter in this volume (see Sauerland, this volume; Rodrigues et al., this volume).

2 From First to Second

The subordinate clause might be an excellent way to report on belief ascriptions, but there are other alternative ways to express beliefs. For instance, beliefs can be reported across sentences (3a). Other alternative ways to express beliefs are direct speech (3b), *according-to*-phrases (3c), and sentences with dislocated clauses (3d).²

- (3) a. It is raining. Ernie thinks that.
 b. Ernie thinks: "It is raining."
 c. According to Ernie, it is raining.
 d. Ernie thinks it, that it is raining.

All the examples in (3) are appropriate belief reports. In fact, Everett (2005) states that expressing belief reports in main clauses is the common way in Pirahã. This assertion raises a number of interesting questions. For instance, is it the only way this language can express beliefs? And more importantly, how does Pirahã express beliefs about beliefs? This chapter focuses on the question why then is it that sentences with complement clauses are so commonly used for belief reports, at least in European languages? The answer to this question lies in the nature of recursion. The answer might suggest that recursion in language is universal.

Recursion is the process that enables human beings to create infinitely long sentences with a finite set of rules. Recursion is the processes of repetition in a self-similar way. In more mathematical terms, recursion is a function that calls itself ($X \rightarrow Y X$) (Lobina and García-Albea 2009).

When we apply clausal embedding recursively, we can express beliefs about beliefs, i.e., second-order beliefs in the sense of Dennett (1996). The sentence in (4) is a report of the thought balloon in (5).

² As was pointed out by a reviewer, (3a) differs from the other examples in (3). For the first sentence in (3a), the truth is asserted. This is not the case in the other examples. Nevertheless, all the examples are suitable ways of reporting beliefs.

- (4) Ernie thinks that Cookie Monster thinks that it is raining.

(5)

We can construct infinitely long recursive structures with subordinate clauses, but it is almost impossible to express a belief about a belief with only main clauses (Roeper 2007). For example, the three-sentence discourse in (6) is not a report of a belief about a belief, whereas the sentence with the double-embedded clauses in (4) is.

- (6) It is raining. Ernie thinks that. Cookie Monster thinks that.

Note that constructing a belief about a belief on the basis of only main clauses, as in (6), is not entirely impossible. With support from specific pragmatic contexts, a belief about a belief might be created for these sentences. Peter Svenonius (personal communication) provided the example in (7a), which could be understood as a belief about a belief as in (7b), given that the hearer is familiar with the appropriate pragmatic context.³

- (7) a. Malcolm is guilty. The jury thinks that. The judge knows that.
b. The judge knows that the jury thinks that Malcolm is guilty.

However, without such a context, constructing a belief about a belief for a three-sentence ascription is very difficult. Hollebrandse, Hobbs, de Villiers, and Roeper (2008) tested cases as in (6). They tested eighteen American-English children in the ages between 6;3 and 6;11 (mean age: 6;9) on prerecorded stories: (8) is one of these stories. Thirteen adults were tested as well.

- (8) Jimmy and his sister live next to a bridge.
The bridge is broken.
Jimmy knows that.
His sister doesn't think that.

After this short discourse, participants were asked to answer either one of the two questions in (9). Participants were also asked to justify their answer.

- (9) a. Will his sister warn Jimmy?
b. Will his sister cross the bridge?

³ As was pointed out by a reviewer, the order *know* and *think* might make a difference. How it makes a difference is unclear and I will leave it to further research.

Figure 2.1 Results for anaphoric relations in discourse (adult participants, N=13)

Participants responded correctly when the target was an instance of single embedding. In this case all participants gave an answer based on a single-embedded construal, *His sister doesn't think that the bridge is broken*. Participants answered *yes* for (9a), because she did not think the bridge was broken and *no* for (9b), because there was no reason not to cross the bridge. The double-embedded constructions – *no* to (9a) and *yes* to (9b) – however, cannot be supported by clarifications. Participants consistently avoided explanations on the basis of double-embedding, and instead gave irrelevant answers such as *No, she is afraid of bridges* for (9a) or *Yes, she likes her brother* for (9b). The results for the adult participants are given in Figure 2.1.

The observation that it is almost impossible to express a belief about a belief with a discourse of independent main clauses also holds for the other examples in (3). These examples cannot easily be extended to expressions of second-order beliefs, i.e., beliefs about beliefs, as in (10) (the #-sign indicates the lack of the double-embedded belief) (Hollebrandse 2010; Hollebrandse and Roeper 2007).

- (10) a. #Ernie thinks: "Cookie Monster thinks: 'It is raining.'"
 b. #According to Ernie according to Cookie Monster it is raining.
 c. #Cookie Monster thinks it, that Ernie thinks it, that it is raining.

One might argue that the construction in (10a) does not involve complementation. However, Collins and Branigan (1997) argue that the quote in direct speech has the same complement structure as that-clauses in indirect speech.

Collins and Branigan (1997) argue for a complement status on the basis of quotative inversion (11). They explain the fact that the inflected verb and the

subject are inverted as a case of V-second. The immediate consequence of that analysis is that the quote itself should be in a complement position.

(11) “The man,” said Mickey, “was going home.”

Hollebrandse (2000, 2007) finds that young children take the quote as a complement and they can even extract out of it. Children gave long-distance answers to the question in (12).

(12) How did Deanne ask: “Can I ride a bike?”

We can conclude that the linguistic freedom to express beliefs at a first-order level disappears at second order, at least for European languages. In European languages, the “designated” form⁴ to express beliefs about beliefs is the recursive clausal embedding, i.e., it is the *that*-clause which allows syntactic recursion and therefore can express embedded propositions or beliefs.

3 Questions

In the previous section, we have observed that there is a designated construction in European languages for expressing beliefs about beliefs, namely the complement clause under a mental state verb. This raises three questions. First, we can ask why the sentence with double-embedded clauses is the designated construction. Second, we can wonder how universal the observation is that the complement clause is the designated construction for expressing recursive propositions. It is conceivable that languages other than European languages have picked out other constructions to express beliefs about beliefs. In other words, some languages might opt for the complement clause, whereas other languages might choose to do this with, for instance, the *according to*-constructions or independent main clauses. Third, we can raise the question of how to experimentally test multiple belief ascriptions.

This chapter will focus on the first question. Although the second question is interesting, we leave it mostly unanswered in this chapter. New analyses of empirical data of Teiwa, a Papuan language, and Pirahã, however, indicate that in these languages, the complement construction is used to report beliefs (for Teiwa, see Sauerland, Kratochvil and Hollebrandse (in prep) and for Pirahã, see Sauerland (this volume)). The third question will be addressed in Section 5 by presenting experimental designs previously used in child language.

4 Direct and Indirect Recursion

To address the first question, we need to have a closer look at recursive rules. There are two forms of recursion: direct and indirect recursion. Direct recursion

⁴ One can wonder, as one of the reviewers did, whether languages have designated constructions to express meaning. What is meant here is that languages have highly frequent forms to do so.

is a rule that calls itself: like something of the form $X \rightarrow X Y$, which has a single loop to form a string. Indirect recursion is a set of rules in which the looping occurs over two or more rules. One of the earliest linguistic recursive set of rules involved the construction of embedded clauses (Chomsky 1965), as in (13).

- (13)
$$\begin{array}{lll} S & \rightarrow & NP VP \\ VP & \rightarrow & V S \end{array}$$

Examples of direct recursion are cases of coordination and some cases of PP-recursion. Indirect recursion creates embedding and as such the possibility of reporting on second-order beliefs (Dennett 1996). Indirect recursion is more interesting because it creates layers in the structure that can contain semantic information that “blocks” recursion, i.e., it blocks the flow of information from clauses embedded lower in the structure. Evaluative predicates are examples of such cases.

4.1 *Evaluative Predicates*

The essence of belief reports is that the speaker can disassociate himself or herself from the propositional content of the belief. In this respect, belief reports channel thoughts through embedded structure. A speaker wants to express a certain belief or thought to another person, without committing himself or herself to the content of that belief or thought. Semantically, embedding is a way of linking propositions. Clauses express propositions. The meaning of those clauses in embedded structures is passed on through the embedding verb of the higher clause and the complementizer. Hollebrandse and Roeper (2007) observe that it is only the propositional content of meaning that is relevant in recursive embedding, i.e., sentences with multiple embedded clauses link meaning in its barest form. The idea is that only the propositional content of the meaning is linked and not, for instance, presuppositional attributions or pragmatic contributions to the meaning.

For instance, the verb *consider* can embed a clause (14), but only once (15). Sentence (15) is strange, because it recursively embeds more than just the propositional content of the meaning. In other words, its meaning includes more than just the proposition: it also includes an evaluation by the main clause subject.

- (14) John considers the food to be tasty.

- (15) #Bill considers John to consider the food to be tasty.

One might argue that the reason for the inability to embed more than once under verbs like *to consider* is that they embed uninflected verbs. However,

the Dutch evaluative verb *vinden* ('to find'), which means discover by testing or experience, embeds inflected complement clauses (16a). These Dutch cases cannot be extended to a second-order level (16b).

- (16) a. Jan vindt dat FC Groningen uitstekend speelt.
 "J. finds that FC Groningen plays excellently."
 b. #Jan vindt dat Piet vindt dat FC Groningen uitstekend speelt.
 "J. finds that P. finds that FC Groningen plays excellently."

Another argument that it is the evaluative nature of the verbs *to consider* and *to find* can be seen when we take out the evaluation. The example in (17) differs from (16) in that it contains a modal verb. The modal verb makes multiple embedding possible by taking the embedded evaluation out. The sentence in (17) is fine, because the sentence only involves one evaluation: the evaluation by the highest subject (*Jan*) and not by the subject (*Piet*) of the first embedded clause.

- (17) Jan vindt dat Piet zou moeten vinden dat FC Groningen uitstekend speelt.
 "J. finds that P. should find that FC Groningen plays excellently."

A third argument is provided by the example in (18). When we change the subject to a subject that is pragmatically unlikely to do an evaluation, such as a life-long teetotaler, the sentence becomes odd.

- (18) #The life-long teetotaler considers the 1999 Bordeaux excellent.

What the examples above show is that only bare propositions can enter a recursive structure. The bareness of the proposition is at the heart of expressing recursive second-order beliefs. Hollebrandse and Roeper (2007) state that restriction in the *Principle of Propositional Exclusivity* (19). The exact nature of this principle is still a matter of further research.

- (19) The Principle of Propositional Exclusivity
 Constrained recursive structures express only pure (bare) non-modified propositions.

5 How to Test These Cases

This section discusses how to test second-order linguistic embedding and belief ascription. The essence of these tests is primarily to test a false belief, i.e., in all cases, protagonists act upon a belief that the participant knows to be false. The set-up includes a second-order belief: one protagonist has a belief about another protagonist's belief. Both tests involved justification questions, which elicited second-order linguistic embedding.

For the verbal false belief task, participants listened to an elaborate story accompanied by four pictures. Each story included two first-order false belief

questions and one second-order false belief question. The participants were also asked to justify their answers. Participants did not hear a double-embedded sentence in the stories. They had to construct the second-order belief and produce a second-order sentence in their justifications. Eight different stories were told to the participants. An excerpt of such a story is given in (20).

(20)

Sam and Maria are playing together. They look outside and see that the church is having a bake sale. Maria tells Sam: "I am going to buy chocolate chip cookies for us there," and she walks away.

Mom comes home and she tells Sam that she just drove past the bake sale. "Are they selling chocolate chip cookies?" Sam asks. "No," mom says, "they are only selling pumpkin pie." "Maria will now probably get pumpkin pie at the bake sale," Sam says.

Probe Question 1: Does Maria know they are selling pumpkin pie at the bake sale?

Maria has arrived at the bake sale. "I would like to buy chocolate chip cookies," she says. "All we have left are brownies," says the lady behind the stall. Since Maria also likes brownies, she decides to get some brownies.

Probe Question 2: Does Sam know that Maria bought some brownies?

First-Order Question: What does Sam think they are selling at the bake sale?

Justification Question: Why does he think that?

On her way back, Maria meets the mailman. She tells the mailman, "I have just bought some brownies. I am going to share them with my brother, Sam. It is a surprise." "That is nice of you," says the mailman. Then he asks Maria, "Does Sam know what you bought him?"

Ignorance Question: What does Maria tell the mailman?

Then the mailman asks: "What does Sam think they are selling at the bake sale?"

Second-Order Question: What does Maria tell the mailman?

Justification Question: Why does she say that?

First-Order Question: What does Sam think they are selling at the bake sale?

Justification Question: Why does he think that?

Hollebrandse et al. (2008)

Hollebrandse et al. (2014)

Figure 2.2 Beliefs held by protagonists in the second-order verbal order test

The story starts out with both protagonists thinking that cookies are sold at the bake sale. The mother then changes the boy's belief to pie, whereas the girl finds out that there are only brownies left and thinks that her brother still thinks they are selling cookies (the second-order belief). Again, no embedded sentences are used in the stories (for more detail, see Hollebrandse et al. 2014). Figure 2.2 gives the different belief construals.

Twenty-one Dutch 6 and 7 year olds were tested (mean age = 6;9, range = 6;2–7;3) and twenty-two Dutch 8 and 9 year olds (mean age = 8;10, range = 8;2–9;11). Seventeen Dutch adults were tested as a control group.

The results for the second-order question are given in Figure 2.3. The children performed well on the first-order question. It is immediately clear from Figure 2.3 that the children often chose a first-order reading in second-order cases in the verbal false belief cases, i.e., *pie* rather than *cookies*. Reality answers were very rare. Adults performed at ceiling. The results for the English children are comparable (see Hollebrandse et al. 2008).

Many children showed that they could construct a second-order belief and justified their answer with a double-embedded sentence (21). But more importantly, children that were not yet able to construe a belief about a belief never gave double-embedded justifications. They only gave single-embedded sentences (22).

- (21) omdat zij nog denkt dat hij nog denkt dat ze
koekjes verkopen
“because she still thinks that he still thinks
that they sell cookies” Child 311, age: 8;10
- (22) omdat ze dat dacht
“because she thought that” Child 317, age: 8;11

The same children who were tested on the bake sale stories were also tested on a low verbal second-order false belief task. This test is called low verbal

Figure 2.3 Percentage of answers to the second-order false belief question

because some language was used in the task, but not language involving mental states, such as propositional attitude verbs (*think, say, believe*), and complement clauses. It is extremely difficult, if not impossible, to convey a second-order belief without the use of any language (Hollebrandse et al. 2014). This test was also used to elicit embedded clauses in Teiwa (Sauerland et al., in prep).

Participants had to watch eight short movies. Four movies targeted first-order false belief and four movies targeted second-order false belief. The movies showed a set of windows which were opened and closed. The first-order movies showed only one protagonist, while the second-order ones showed two protagonists in the windows. The protagonists could see the scene in front of the windows, depending on whether the windows were closed or opened. Two stills of the movies are displayed in (23).

Figure 2.4 Type of answers to the second-order question in the low verbal task

Half of the movies were modeled after the so-called *Smarties* task and the other half after the *Sally-Ann* task (Wimmer and Perner 1983). The essence of these tasks is that either the content of a container is changed (*Smarties*), or an object is moved from one hiding place to another (*Sally-Ann*). Protagonists do not see all the changes and therefore build false beliefs.

The results of the second-order question are given in Figure 2.4. These results are somewhat different from the verbal false belief task. As in the verbal false belief test, participants had difficulty with second-order questions, but there was a large number of reality answers.⁵ All participants performed at ceiling for the first-order questions. Again, adults performed at ceiling.

6 Discussion

This chapter started by showing the tight relation between complement clauses and belief ascription. It also stressed the importance of second-order embedding, because a first-order embedding representation is not generated on the basis of recursion. It is, therefore, the case that first-order belief ascription can be expressed in not only complement clauses, but also in discourse, direct speech, *according-to*-phrases, and in dislocated clauses. The answer to why the

⁵ Additionally, thirty-five English 6 and 7 year olds were tested. They showed a strong preference for the first-order answer.

complement clause is so efficient at expressing second-order beliefs lies in the nature of what is embedded: the clause should just express a bare proposition. As soon as more meaning is embedded, recursive embedding is not available anymore. This can be seen in the difference between the sentences with propositional attitude verbs and those with evaluative verbs.

It is also suggested that the tight relation between complements and beliefs is universal. Although we have not shown that in this chapter, several chapters in this volume suggest that the relation is universal (Sauerland, this volume; Rodrigues et al., this volume).

Two experiments were presented showing how to test multiple embedding of beliefs. The results reveal that second-order belief ascription is developed at a fairly late age. A possible explanation for this is that understanding and reporting on second-order beliefs involves subtle information. However, the subtlety of information could not be the full explanation, since children can acquire subtle linguistic information at a very young age. It is quite conceivable that this relatively late acquisition reflects differences across languages. The language acquisition task then is to find the appropriate constructions to express thoughts and beliefs. Which constructions are designated for certain parts of language could differ across languages. Recursion is one of the phenomena where languages vary. Specifically, languages differ in the constructions that allow recursion, i.e., similar constructions across languages differ in their ability to enter recursion. For instance, Germanic languages allow recursive compounding, but Romance languages resist it. Recursive possessives (*John's father's brother's car*) are fine in, for instance, English and Japanese (Terunuma and Nakato, this volume), but more restricted in Dutch or German (Hollebrandse and Roeper 2014; Pérez-Leroux et al., this volume; Pérez-Leroux et al. 2012).

Returning to belief reports and embedded sentences, some children (even at fairly older ages) gave explanations of the kind in (24). These are interesting because they are combinations of the single-embedded complement clause and the anaphoric discourse case (3). Examples such as these indicate that children seem to be aware of the different systems. The children in (24) are at this age aware of recursion (PP-recursion occurs earlier) (Terunuma and Nakato, this volume), but what these children are not yet fully aware of is which construction to use to express beliefs about beliefs. The example in (24) might very well reflect the cross-linguistic possibilities.

- (24) omdat ze koekjes wou gaan kopen en dat Sam zei dat
because she cookies wanted go buy and that S. said that
“because she wanted to go and buy cookies and Sam said that.”

Child 313, age 9;6

This last observation is important in a cross-linguistic perspective. Given the biological basis of language, the variation found in child language should be reflected in adult languages cross-linguistically. It is still an open question as to how flexible the possibilities across languages are to express second-order beliefs.