WHEN CHILDREN ARE STRONGER THAN ADULTS

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1. Introduction

Ambiguity is a pervasive feature of human languages revealed in a variety of different domains and logic composition is arguably one of them. The problem is evident if we take into consideration sentences containing more than one logic operator.

One example is given by sentences containing a negative operator and a quantificational element in subject position, as in sentence (1) below:

(1) Every horse didn't jump over the fence.

a. Every horse is such as it did not jump over the fence.
b. Not every horse jumped over the fence.

This sentence can be used to describe two different states of the world, illustrated in the paraphrases in (1a-b). According to the first interpretation (1a), it describes a situation in which *none* of the horses of a given set was able to cross an obstacle. The alternative meaning (1b), instead, refers to a different situation in which only *some* of the horses jumped over the fence.

Whatever theoretical solution we adopt for deriving both (1a) and (1b), what is important here is the fact that the hearer of (1) must be able to map this sequence of words onto two distinct logic representations. Given that multiple logic representations are possible for a single sentence, one question to answer for development theories is whether children grasp all the meanings of logical ambiguous sentences.

However, not all sentences with two operators are ambiguous. In fact language might adopt special strategies to avoid ambiguity by means of specific constraints in force on scope assignment. Another issue for developmental theories is to determine whether children are sensitive to language specific rules able to restrict the set of possible interpretations. This point can be illustrated considering the case of polarity items. For example, English existential quantifiers split into two set of items: negative polarity items as *any* (Ladusaw 1979) and the complementary set constituted by positive polarity items as *some.* Contrary to (1), sentence (2) is unambiguous in English and the standard explanation for the impossibility of (2a) relies on the polarity of *some* (Szabolcsi 2004):

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(2) The detective didn't find some guys.

a. *It does not exist any guy found by the detective.
b. There exist some guys such as the detective did not find them.

This additional feature, polarity, specifies that the quantificational meaning has to be processed before the application of the negative operator, or alternatively stated, outside its scope. However, although children are sensitive to polarity from early on (Thornton 1994), their mastery of the quantifier paradigm might fail to show up in sentences where *some* appears within the surface scope of negation.

In one of the first study on the topic, Musolino (1998) claimed that, when children are called to judge the truth condition of (2), they fail to verify the adult reading (2b). But why children should lack reading (2b)? Musolino (1998) argued that the missing reading (2b) is special in that it is the one in which the logic processing of the quantifiers does not respect the order dictated by surface scope. This observation was initially supported extending the observation to the early interpretation of (1), where regardless of the fact that no restriction exists in English on the interpretation of universal quantifiers, children also lack the inverse scope reading (1b).

Taken together, children's preference for interpretations (1a)-(2a) points toward the conclusion that they initially have a narrower range of interpretations and that they always process logic operators respecting the stack created by surface scope relations, regardless of other competitive rules of the grammar, as polarity restrictions.

However, things are not so straightforward as suggested in Musolino (1998), and those findings have been mined by successive experimental evidence (Gualmini 2003, Husley et al. 2004, Musolino & Lidz 2004) showing that children are able to access the inverse scope readings (1b)-(2b), if appropriate pragmatic conditions are taken into account in the experimental design. At the present state of the debate, it seems that children have both surface and inverse scope interpretations, proviso that interpretations are felicitous in the context.

The goal of this paper is to broaden the discussion considering operators of a different kind. In fact the problem of ambiguity resolution goes beyond the case of nominal quantifiers and every scope bearing element can be suitable to observe children's logic competence. Modal verbs seem to be a good candidate, since their semantic can be reduced to quantification (Hintikka 1962, Lewis 1973) and we expect to find the same ambiguities found with nominal quantifiers. This prediction is borne out as testified by the following sentence from Italian, where the modal verb can be interpreted both within and outside the scope of negation:

(3) Milena non deve prendere l'ultimo treno.
Milena not must take the last train

a. It is necessary that Milena doesn't take the last train.
b. It is not necessary that Milena takes the last train.

Notice that here the linear order between the modal *deve* and negation does not constraint the interpretation. In fact, sentence (3) can be interpreted either as expressing the necessity not to do a given action (3a), for example in a context in which we know that a girl must absolutely avoid to take the train late at night, or as (3b), true if Milena has the possibility to take the car instead of the train. This example shows that, from the point of view of scope assignment, we are in front of an extremely similar phenomenon to the one observed with universal quantifiers.

What about language-specific constraints? They can also be observed, as in the following sentence (4), with the modal *potere*:

(4) Milena può non mangiare cibo piccante.

a. *It is not possible that Milena eats spicy food.
b. It is possible that Milena doesn't eat spicy food.

Sentence (4) is not ambiguous, and it may only express the possibility not to eat spicy food and never a prohibition, with negation taking narrow scope below the modal. While it is unclear if such a constraint might be linked to the polarity of *potere*[1], we have a case in which logic ambiguity is cut by some block active on Italian, as in the case of *some* in English.

Again we are facing the problem from where we started: in order to master sentences with modal and negation, children need to have two representations for ambiguous sentences as (3) and to know language specific constraints which rule out interpretation (4). At the current state of research little is know about children's interpretation of the relevant constructions, and a first question is whether children have access to both LF representations in negative modal sentences. A second question deals instead with the acquisition of constraints active on interpretations. The issue is to assess if children are sensitive from early on to language specific disambiguation strategies and this amount to ask whether children correctly exclude meaning (4).

In the next section I will consider first the case of negative sentences with nominal quantifiers and then I will introduce some empirical findings related with the interpretation of modals. However many questions are still open, and in section 4 a new experiment will be presented.

[1] A more accurate description of the constraint active on the relative scope of negation and the modal *potere* can be stated in terms of surface c-command. In (4) *può* c-command negation and it takes wide scope over it. On the contrary, when *potere* follows negation, it can only be interpreted within its scope. See section 4.1.

2. Early Logic Composition and Inverse Scope Readings in Negative Sentences

The problem of determining if children do have multiple interpretations for a potentially ambiguous sentence has been first addressed by Musolino (1998). He considered the well know ambiguity found with nominal quantifiers in negative sentences as (1) and (2), repeated here as (5) and (6).

(5) Every horse didn't jump over the fence.

(6) The detective didn't find some guys.

The logic beyond the experimental design was that if children lack one of the two interpretations, they will lack the harder/marked one. Intuitively, if we place the matter along the dimension surface–inverse scope, this last representation poses additional problem for the child, who has to learn that logic composition is relatively unconstrained by surface c-command relations.

This idea was initially confirmed by a series of experiments which strengthen the hypothesis of an isomorphic LF/PF mapping, but a successive set of empirical findings has shown that children are able to access also the inverse scope reading (Gualmini 2003) given the pragmatic felicitousness of the experimental setting. Thus the assumption that children initially lack covert logic operations, necessary to build the inverse scope reading, has revealed to be unwarranted. Moreover, there is no evidence that covert logic operations pose a harder challenge for language learners.

However, although the observation of any scope bearing element might help to verify the prediction of LF/PF isomorphism, only nominal quantifiers have been taken into account. As we saw in the preceding section, also modal verbs can be considered and their observation will help to broaden the empirical base of the debate.

One of the first studies looking explicitly at the interaction between modals and negation is Moscati & Gualmini (2008). The starting assumption was the same underlying Musolino (1998) and Musolino et al. (2000), namely that inverse scope is marked and that it is the most difficult interpretation to grasp, since it involves non-visible syntactic operations. With this view in mind, it follows that such interpretation is the one to prime and to observe in the experimental setting. Consider the following sentence:

(7) The red ball cannot be with the yellow ball.

a. It is not possible that the red ball is together with the yellow ball.
b. *It is possible that the red ball is not together with the yellow ball.

Even if the elements <can, not> might differently combine originating the two interpretations in (7), surface scope (7b) is ruled out in English and the inverse scope reading (7a) is the sole target-consistent logic structure.

The prediction of isomorphism is that, if children lack covert operations, they will not be able to correctly process sentence (7) and a bias toward the deviant surface reading (7b) is expected. In Moscati & Gualmini (2008) children were presented with sentence (7) and they show no difficulty with meaning (7a), contrary to the prediction of isomorphism. This result shows that inverse scope is accessible also in the case of modals.

Given the input un-ambiguity of the relevant sentence in English, we may wonder if the overwhelming evidence available to children in favour of (7a) blocks (7b). To control for this factor, in a second experiment M&G (2007) looked at Italian sentences as (8) with the modal *dovere* where both readings are possible.[2]

(8) L'indiano non deve cavalcare la tigre.

a. It is necessary that the Indian does not ride the tiger.
b. It is not necessary that the Indian rides the tiger.

Here the input does not exclude the surface scope interpretation (8b). However this doesn't seem to affect children's response, which again does not show any bias toward surface scope.

Even if those findings show that children do have inverse scope readings, this does not entail that children already have an adult competence. In fact, given the underlying assumptions about the markedness of inverse scope readings, those interpretations were the only ones which have been checked. The logic according to which if the 'harder' scope assignment is available than all the other readings will be available as well might be misleading. First, because we do not know if inverse scope is really harder. Second, difficulties might be measured along different dimensions and what is harder in some respect can be easier along some other scale.

In the next section I will present a different way to consider complexity which goes beyond the distinction inverse/surface.

3. From Covert Operations to the Strongest Meaning Hypothesis

In Moscati & Gualmini (2008) we found early inverse scope readings when they were required (English) or allowed (Italian), and no deviation from adult grammar was detected. However the assumption that inverse scope is the last and hardest thing to get is not

[2] Intonation can make prominent one of the two readings. The stress on DEVE seems to facilitate its narrow scope/surface reading (i). However, also with a plain intonation, this reading is still available and example (ii) is also acceptable:

(i) l'indiano non DEVE cavalcare la tigre, se non ne ha voglia.

(ii) l'indiano non deve cavalcare la tigre, se non ne ha voglia.

'It is not necessary that the Indian rides the tiger, if he doesn't want.'

empirically motivated. Moreover nothing insures us that children's ability to deal with covert operations will give them full-fledged adult-like competence. In particular, the readings accessed by children are *strong* readings. Let me illustrate this point. Consider the two kinds of sentences given to English and Italian children in Moscati & Gualmini (2008), and the selected interpretation:

(9) The red ball cannot be with the yellow ball.

a. not > possible (Inverse Scope, selected)
b. possible > not (Surface Scope)

(10) L'indiano non deve cavalcare la tigre.

a. necessary > not (Inverse Scope, selected)
b. not > necessary (Surface Scope)

Notice that changes in the choice of the modal and in the linear order cancel each other out and interpretations (9a) and (10a) are truth conditional equivalent:

(11) not > possible = necessary > not

From this follows that regardless of the quantificational strength and the surface c-command structure, children do not have problem in accessing the meaning in (11). Thus the interpretations selected by children do have something more in common than being either inverse or surface: they have the same meaning.

Those two equivalent meanings (9a)-(10a) have another important characteristic in common. This is the ability to entail the other competitive interpretations given in (9b)-(10b) and under this respect, they have stronger truth conditions:

(12) not > possible → possible > not

We can capture this fact by a more formal definition of strength:

(13) Informational Strength:
proposition α is stronger than proposition β if:
α asymmetrically entails β

At this point it is easy to check that children selected readings are always the stronger ones, a finding which is consistent with the Semantic Subset Principle proposed by Crain at al. (1994). This lead to the conclusion that children tested in Moscati and Gualmini (2008) have no problem in accessing inverse scope readings, when they are strong.

If informational strength triggers the preferred interpretation, we may expect that this factor will overwhelm the other two factors of complexity just discussed: covert operations and target consistency. In the next section I will present an experiment which tries to tease apart the role of informational strength.

4. Testing the Strongest Meaning Hypothesis

There are at least three ways in which one interpretation can be considered to be harder. The first is input consistency: an interpretation might be ruled out by language specific constraints and it can be considered to be harder to acquire and to compute on the basis of the available linguistic data. The second way to consider complexity is the one assumed in Musolino (1998) and in Moscati and Gualmini (2008), in which covert operations might involve an additional processing load. Finally, the third way is the one illustrated before and deals with the informational strength of a given interpretation, in conformity with the Semantic Subset Principle.

In this experiment we want to test if the third factor might overwhelm the other two and if the Strongest Meaning Hypothesis is grounded. To do so we have to find a case in which the strongest interpretation doesn't coincide with the surface scope interpretation and it is not consistent with the linguistic input. Such a case can be found in Italian, in sentences where the modal verb *potere* c-commands the negative operator[3]:

(14) Il contadino può non dare le carote all'elefante.
the farmer might not give the carrots to-the elephant

a. *It is not possible that the farmer gives carrots to the elephant.
b. It is possible that the farmer doesn't give carrots to the elephant.

In this sentence, only the surface scope reading (14b) is allowed and this reading is the weaker one since it doesn't entail (14a):

(15) può > non −/→ non > può

By the Strongest Meaning Hypothesis, the prediction is that children will encounter problems with (14b). No other account, neither isomorphism nor frequency, expects (14b) to be marked.

4.1. Materials

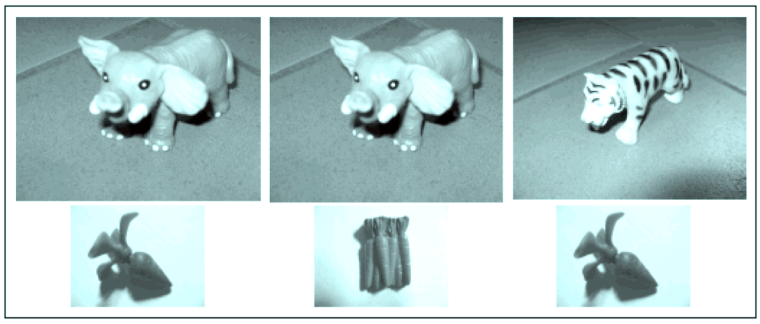
In the experiment a standard TVJT (Crain & Thornton 1998) has been used and children heard 4 sentences as (14) in story contexts acted out with props and toys. The following is one of the four stories:

[3] It is unclear why the reading (14a) is blocked. One possible explanation is that *potere* belongs to the class of *restructuring verbs*, which take a sentential complement and through a *restructuring rule* (Rizzi 1982) a biclausal structure is transformed in a monoclausal one. The presence of negation might block such a rule (Rizzi 1982, Kayne 1989) and it will be impossible to eliminate the clause boundary. The negative operator is than unable to cross a CP border (Moscati 2006, 2008) and its scope is bounded to the lower clause. For this reason inverse scope reading of negation over the modal is ruled out.

There is a farmer with some turnips and carrots and he has one tiger and two elephants to feed. The farmer first goes to the tiger, which says that it doesn't like carrots. Thus the farmer decides to give it a turnip. Then he goes to the elephants and they say that they don't have any preference. The farmer decides to give a turnip to the first elephant and a carrot to the second one.

The visual display at the end of the story is the following:

Fig.1.



We then asked a puppet to describe what happened in the story. The puppet answers uttering a sentence with the modal *potere* preceding negation, as in the target sentence (14) repeated here as (16):

(16) Il contadino può non dare le carote all'elefante.

a. *It is not possible that the farmer gives carrots to the elephant.
b. It is possible that the farmer doesn't give carrots to the elephant.

Since there is one elephant (the one at the left in Fig.1) without carrots, it follows that it is possible not to give carrots to the elephant: the weak reading (16b) is true. We expect that this reading will be readily available for children if they are insensitive to the informational strength of the sentence, since the reading (16b) doesn't involve covert operations and it is fully target consistent.

Between the 4 target trials, 4 fillers/controls were inserted. Controls are divided into two categories and two stories were presented for each control. In the first type of controls (Type A) affirmative sentences containing the modal 'potere' are given to children after the presentation of a brief story:

There is a king who has some magic objects: two swords and a harp. The swords give the ability to run fast to the one able to hold it, while the harp gives the ability to fly if someone is able to play it. Semola goes to the king and he first tries to play the harp. He has success and he is now able to fly. Then he tries with the swords. He tries the first sword, but it is too heavy and he fails. He tries then with the second one, and this time he manages to lift it and he runs away fast.

At this point, a puppet is asked if Semola can lift the sword. The puppet answers with the

following sentence:

(17) Semola può sollevare la spada.

'Semola can lift the sword.'

This control is included to test if children have problems with the modal *potere* and if children identify the definite *the sword* with the second sword, the one which made the sentence true. Definite determiners were chosen in the target condition in order to avoid the insertion of another scope-bearing element as an indefinite. This choice may be a source of confusion and children rejection of the target sentence might be due to the inappropriateness of the definite determiner.

In the second control (Type B), we gave children sentences with a negative operator linearly preceding the modal 'potere' after a story like the following:

> *There is a Pilot who wants to go out and he is torn between taking a motorbike or an F1 car. He decides to take the motorbike, but when he tries to climb on it, he falls down since it is too high. He tries again, but he falls another time. He changes his mind and takes the car without problems.*

We ask the puppet if the pilot can drive the motorbike. The puppet then utters the following statement, true under the previous context:

(18) Il pilota non può guidare la moto.
the pilot not can drive the motorbike

a. It is not possible that the pilot drives the motorbike.
b. *It is possible that the pilot doesn't drive the motorbike.

Again, children are expected to accept the sentence if they can compute the meaning of negation and the modal, which now is the strong reading. This second control has been included to test whether children are able to process the negative operator with modal verbs and also to test if they have problems in accessing surface scope/strong readings.

4.2. Participants

20 monolingual Italian speaking children (Age: 3;9–5;7. Mean 4;5) from two kindergartens in the Siena area.

4.3. Results

Let us first look at the results of the controls. In the Type A controls, children reveal not to have particular difficulties with declarative modal sentences, neither with the use of the definite article. Table 1 illustrates the results:

Table 1. Type A - Children's acceptance of true declarative sentences

Condition	Affirmative True		
Trials	Trial 1	Trial 2	Tot.
Acceptance	17/20 (85%)	16/20 (80%)	33/40 (82.5%)

A lower performance is found instead with negative sentences with a modal verb. Children only accept the target sentence 65% of the times. Results are given in Table 2:

Table 2. Type B - Children's acceptance of negative sentences

Condition	Negative True		
Trials	Trial 1	Trial 2	Tot.
Acceptance	13/20 (65%)	13/20 (65%)	26/40 (65%)

Acceptance with negative sentences seems to be relatively poor. However the rate is kept low by the results of few children, which are partially the same failing Type A controls (see Appendix A for individual data). Those five children have a strong tendency to answer 'wrong', and since the adult response to the target sentence should be 'right', this will bias the result toward the experimental hypothesis. In general, those children present problems with the experimental design and show scarce attention to the task. For those reasons, we will consider only children which accepted at least one control for each kind. This permits us to look at the data relative to children which show no particular problem with (i) the modal *potere*, (ii) with the use of the definite determiner and (iii) with negative modal sentences and which show no evident trace of a negative bias.

Table 3. Results - at least the 50% of correct answers for each control

Condition	Affirmative False	Negative True
Acceptance	28/30(93.3%)	26/30(86.6%)

Now we turn to the test sentences, comparing the results with weak interpretations to the results of the controls relative to the 15 children which accept at least one sentence for Type A and Type B reported in Table 3.

Target sentences

Each child heard 4 stories, and at the end of each story they are asked to judge the puppet's statement. Remember sentence (16), repeated again as (19):

(19) Il contadino può non dare le carote all'elefante.

a. *It is not possible that the farmer gives carrots to the elephant.
b. It is possible that the farmer doesn't give carrots to the elephant.

The story makes sentence (19) true under the weak interpretation, which is the only one permitted in adult Italian. However, Table 4 shows that children tend to reject this sentence in the majority of the cases, and they accept it less than the 30%.

Table 4. Acceptance for target sentence

	Story 1	Story 2	Story 3	Story 4	Tot.
Acceptance	6/14	5/14	4/15	4/15	19/58 (32.7%)

Since it is possible that children reject the target sentence for some unknown reason, every time that the children rejected the target sentence we asked for an explanation. In the vast majority of the cases, the explanation was consistent with the strong reading, confirming that a wrong logic mapping was the source of children's rejection. In 3 cases the children give an explanation inconsistent with the strong reading (19) (for example: *because elephants are strange)*. Excluding those responses and making a conservative count, we still have a preference for the rejection of the target sentences (19/55; 34.5%).

As it is possible to observe by looking at this table, children present a much lower acceptance of the target sentence if compared with adults.

Table 5. Acceptance excluding inconsistent rejections

Group	Adult	Children
Acceptance	40/40 (100%)	16/52 (30.7%)

Remember from the previous discussion, that this result is largely unexpected if children have problems only with inverse scope readings, since the target sentence present no covert operation.

5. Discussion

The experiment shows that 5years-olders, when presented with sentence (19), fail to interpret it in accordance with the adult interpretation. This result is surprising either under the isomorphic account or under any frequency based explanation since the adult reading presented in (19b) is the surface scope interpretation and it is the only one heard in the speech. The experiment then shows that neither input frequency nor inverse logic operations are crucial. What seems to be really special about the selected reading is semantic strength, defined in terms of asymmetric entailment as stated in (13).

This result suggests that initially children might have a narrower range of interpretations, giving a preliminary answer to one of our initial questions regarding whether children do have both LF representations. Whether those results might be biased by pragmatic factors still to be determined (see Moscati, to appear).

Concerning the other question posed in the beginning of this paper, namely children's sensitivity to language specific constraints active on interpretation, it seems that they might be violated or acquired later, given that children preferentially access the non-adult reading (19a) in order to adhere to the Strongest Meaning.

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APPENDIX

Individual responses to controls

Child	Acceptance in Affirmative True		Acceptance in Negative True	
	#	%	#	%
1	2/2	100	2/2	100
2	**0/2**	**0**	**0/2**	**0**
3	1/2	50	1/2	50
4	2/2	100	2/2	100
5	1/2	50	1/2	50
6	2/2	100	2/2	100
7	2/2	100	2/2	100
8	2/2	100	1/2	50
9	2/2	100	2/2	100
10	**0/2**	**0**	**0/2**	**0**
11	2/2	100	1/2	50
12	2/2	100	2/2	100
13	2/2	100	**0/2**	**0**
14	2/2	100	**0/2**	**0**
15	2/2	100	2/2	100
16	2/2	100	2/2	100
17	2/2	100	2/2	100
18	1/2	50	**0/2**	**0**
19	2/2	100	2/2	100
20	2/2	100	2/2	100
Tot.	33/40	82.5%	26/40	65%