

Testing the QUD Approach: Children's Comprehension of Scopally Ambiguous Questions

Federica Di Bacco, Lyn Tieu, Vincenzo Moscati, Raffaella Folli,
Christina Sevdali, and Jacopo Romoli

1. Introduction

Children and adults have been reported to differ in their interpretation of scopally ambiguous sentences such as *Every horse didn't jump over the fence* (Musolino 1998; Gualmini 2004; Gualmini et al. 2008; Musolino & Lidz 2006; see also Lidz & Musolino 2002; Musolino et al. 2000; Musolino & Lidz 2006; Krämer 2000; Moscati & Crain 2014; Moscati et al. 2016, among many others). A recent approach in the literature treats this difference as fully pragmatic in nature. In particular, Gualmini et al. (2008) have proposed an explanation based on what they call the Question-Answer Requirement (QAR), which locates the source of the difference in the understood Question Under Discussion (QUD) in the context. The main idea behind the QAR is that any sentence is to be understood as an answer to a QUD. As a consequence, in the case of scopally ambiguous sentences, a given reading of the sentence is accessible (to adults and children) only if it constitutes a possible answer to the contextual QUD. Children and adults are then claimed to differ only in how they handle and accommodate QUDs. In particular, if the reading that would answer the salient QUD is false in the context, adults, but not children, are able to accommodate a new QUD in order to access the true interpretation of the ambiguous sentence.

Given that it locates the difference only in the way QUDs are managed, the QAR approach predicts that if the effects of the QUD are controlled for, children and adults should perform alike. In this study, we indirectly probed the role of the QUD in scope ambiguity resolution by moving to a linguistic context where there is no sentence that constitutes an answer to the relevant QUD. To do so, we tested children's and adults' comprehension of scopally ambiguous *questions*, rather than declaratives. The main finding of our experiment is that 4–6-year-old children and adults display the same rates of access to the inverse scope readings of such questions. This finding is consistent with a general assumption underlying the QAR approach, which is that there is no grammatical difference in children's and adults' ability to access inverse scope readings. Indeed, once the QUD factor is controlled for, the two groups perform alike.

We further discuss the compatibility of our results with two alternative hypotheses concerning the QAR and the interpretation of questions. The first possibility is that the QUD is simply not a factor that affects the interpretation of questions. This would explain why we found no difference between children and adults. In this scenario, the QAR approach to scope interpretation should not be extended to questions. The second possibility is that the QAR approach should be formulated in such a way that it can be extended to explain performance on questions, in particular invoking a notion of super-question and sub-question (Roberts, 1996). In this latter scenario, the lack of a difference between children and adults would be due to the fact that our experimental contexts made salient a super-question that facilitated inverse scope interpretations. We end by discussing a possible formulation of such an extended QAR approach to questions, and sketch a follow-up experiment that could distinguish between the two scenarios just mentioned.

* Federica Di Bacco, Ulster University. Lyn Tieu, Laboratoire de Sciences Cognitives et Psycholinguistique, ENS Paris. Vincenzo Moscati, Università degli Studi di Siena. Raffaella Folli, Ulster University. Christina Sevdali, Ulster University. Jacopo Romoli, Ulster University.

2. Background

2.1. Children and scope ambiguity resolution

2.1.1. Grammatical account and pragmatic felicity

Sentences that contain more than one scope-bearing element, such as negation, quantifiers, or modal verbs, are often ambiguous. For example, a sentence like (1) has two possible interpretations: a *surface scope* reading on which the universal quantifier *every* takes scope over the negation, which we could paraphrase as in (1-a), and an *inverse scope* reading on which the negation takes scope over *every*, paraphrasable as in (1-b).

- (1) Every horse didn't jump over the fence.
- | | |
|---|------------------------------|
| a. Every horse is such that it didn't jump over the fence | <i>Surface Scope reading</i> |
| b. Not every horse jumped over the fence | <i>Inverse Scope reading</i> |

In one of the earliest studies on scope ambiguity resolution in children, Musolino (1998) presented sentences like (1) to preschoolers (aged 4–6 years) and adults in a Truth Value Judgment Task (Crain & Thornton, 1998). Each sentence was provided as a description of a short story that would make it true on its inverse scope interpretation and false on its surface scope reading (e.g., only two out of the three horses jumped over the fence). Musolino found that children would consistently reject (1) as false in such contexts, providing evidence that they were accessing only the surface scope interpretation of the sentence. Adults, on the other hand, had no problem accessing the inverse scope reading of the sentence and accepted it as true in the vast majority of cases. Based on these results, one could hypothesize that the difference between adults and children is of a grammatical nature. That is, at this particular stage of development, children are able to generate surface scope interpretations of scopally ambiguous sentences but not inverse scope interpretations.

A number of studies have since challenged this hypothesis (Gualmini 2004; Musolino & Lidz 2006; Krämer 2000, among others), at least on its most radical version, which would claim that children are unable to access inverse scope readings altogether. In particular, Gualmini (2004) has noted that children's rejection rates for inverse scope readings vary considerably across experimental items. Researchers have since explored the possibility that the story contexts in which the sentences were presented had an effect on their interpretation. In an experiment similar to the one presented in Musolino (1998), Gualmini (2004) tested 4- and 5-year-old children's comprehension of sentences containing negation and the existential quantifier *some*, such as (2), which could be interpreted roughly as in (2-a) or (2-b).

- (2) The troll didn't deliver some pizzas.
- | | |
|---|------------------------------|
| a. The troll didn't deliver any pizzas. | <i>Surface Scope reading</i> |
| b. Some pizzas were not delivered by the troll. | <i>Inverse Scope reading</i> |

The sentence in (2) was presented as the description of a story in which a troll has to deliver four pizzas, but he ends up losing two of them, and so only manages to deliver two out of the four pizzas. The sentence is therefore false on its surface scope interpretation (2-a) but true on the inverse scope reading (2-b). Contrary to the findings in Musolino (1998), children actually accessed the inverse scope reading of (2) and similar sentences 90% of the time. Such a finding poses a challenge to the idea that children's previous failure to access inverse scope readings were due to an inability to generate such readings altogether.

Based on these results, Gualmini (2004) proposes an alternative pragmatic explanation of why children and adults differ in their interpretation of scopally ambiguous sentences. Gualmini observes that the sentences that had previously been investigated involved negation, and connects the scope findings to well-known observations about felicity conditions on the use of negation. In particular, it has been observed that negative sentences are normally used to point out a discrepancy between the expected outcome of a situation and its actual outcome (Wason, 1965; De Villiers & Flusberg, 1975). In other words, the context has to supply such an expectation for a negative sentence to be felicitous. The story provided for (2) had made it clear that the troll was supposed to deliver all the pizzas, therefore making the interpretation in (2-b) felicitous. In Musolino's experiment, however, the context story for (1) did not

introduce an expectation that all three horses would jump over the fence, making (1-b) less felicitous. To summarize, on Gualmini's pragmatic account, children and adults do not differ in their grammatical abilities, but rather in how they react to an infelicitous sentence: adults are able to overcome the infelicity, and accept the sentence (on its true reading); children, on the other hand, are unable to accommodate the infelicitous sentence and therefore tend to reject it.

2.1.2. *The Question Answer Requirement approach*

The claim that the difference between children and adults in scope ambiguity resolution can be explained in terms of a pragmatic difference was subsequently refined and extended beyond the case of negative sentences. In particular, Gualmini et al. (2008), building on work by Roberts (1996) and others, proposed that the relevant factor in scope ambiguity resolution is the understood Question Under Discussion (QUD). The idea is that any declarative sentence is understood as an answer to a particular QUD. And, as a consequence, each reading of a scopally ambiguous sentence also has to be understood as an answer to the salient QUD at that moment. Gualmini et al. (2008) call this pragmatic condition the Question and Answer Requirement (QAR). To illustrate, let us go back to the sentence in (1) and imagine that the context made relevant the question in (3). In this case, it is clear that both (1-a) and (1-b) would constitute good answers to the question, with both leading to a *no*-answer to (3). Therefore, according to the QAR approach, either reading could be selected.

(3) Did every horse jump over the fence?

On the other hand, if the context made salient the question in (4), only the surface scope interpretation in (1-a) would constitute a good answer. The inverse scope interpretation in (1-b) would not allow us to conclude a negative or positive answer to (4). Therefore, if the understood QUD for (1) is (4), according to the QAR, (1) can only be interpreted on its surface scope reading.

(4) Did any horse jump over the fence?

Of course, the influence of the QUD on the interpretation of sentences like (1) by itself does not allow us to explain the *difference* between children and adults. The additional ingredient that Gualmini et al. invoke is the following. While the QAR is always in place for both children and adults, the two groups differ in their pragmatic ability to manage QUDs. That is, in an attempt to access true interpretations in the context (sometimes referred to as adhering to a Principle of Charity, (see Grice 1975, among others), adults can sometimes set aside the relevant QUD made salient by the context, and accommodate a new one that can be answered by the true interpretation of the ambiguous sentence. Children, on the other hand, are unable to accommodate a different QUD, and therefore have to select the interpretation that provides a good answer to the salient QUD, whether that interpretation is made true or false in the given context. This difference would also underlie the divergence between children and adults reported in studies like Musolino (1998), as well as potentially accounting for the variation across experimental contexts, as shown by Gualmini (2004) and others.

2.2. *Scopally ambiguous questions*

Summarizing, the QAR approach places the difference between children's and adults' interpretations of scopally ambiguous sentences entirely in the management of the QUD. A prediction of this approach is therefore that if QUD effects are controlled for, we should observe no difference between the two groups. In the present study, as a way of controlling for QUD, we investigated children's and adults' interpretations of scopally ambiguous *questions*, rather than scopally ambiguous declarative sentences. The idea is that in this linguistic context, the different readings of the questions no longer constitute *answers* to the salient QUD, and we should therefore observe no difference between children and adults.

A natural step would be to examine the same sentences that have been used in previous studies of children's scope ambiguity resolution, but in interrogative rather than declarative form. Given most previous studies used sentences involving negation, this would mean investigating participants' interpretations of negative questions. Interpreting such negative questions, however, would present a variety of

complications. For instance, it is well known that negative questions are subject to a bias that may influence the answer they receive (Romero & Han, 2004), and moreover that the mapping between *yes/no* answers and questions containing negation is also not straightforward (Krifka 2001 among others). For these reasons, we investigated questions containing two quantifiers, such as (5).

- (5) Did a doctor take each pencil?
- a. Is it true that there is a single doctor that took each pencil? *Surface scope reading*
 - b. Is it true that for each pencil there is a doctor who took it? *Inverse scope reading*

(5) has two possible interpretations: a surface scope reading, in which what is being questioned is whether there is one single doctor who took each of the pencils; and an inverse scope reading, in which the question is about whether each of the pencils was taken by a (possibly different) doctor. While research on children's scope ambiguity resolution has mostly focused on sentences containing negation and a quantifier, the declarative version of (5) and similar sentences, e.g., (6), have received considerable attention in research on adults (Johnson-Laird 1969; Gillen 1991; Kurtzman & MacDonald 1993; Tunstall 1998; Anderson 2004 among others).¹

- (6) A doctor took each pencil.
- a. There is a single doctor that took each pencil.
 - b. For each pencil there is a doctor who took it.

3. Experiment

Children and adults were tested on their interpretation of questions like (5), repeated below, which were posed at the end of a short story context that would elicit a *yes*-response if the question was interpreted on its inverse scope reading, and a *no*-response if the question was interpreted on its surface scope reading.²

- (7) Did a doctor take each pencil?
- a. Is it true that there is a single doctor that took each pencil? *Surface scope reading*
 - b. Is it true that for each pencil there is a doctor who took it? *Inverse scope reading*

¹ In particular, numerous experimental studies have shown that the universal quantifier is generally unlikely to take scope over the existential. The majority of these studies, however, have paired the existential quantifier with the universal *every*. Various explanations have been proposed for this preference for surface scope. Initial proposals (Ioup, 1975) claimed the lexical properties of each quantifier influenced its likeliness to take wide scope, with *every* ranking lower than *a* in likeliness. Later, researchers focused on the possibility that computing the inverse scope of (5) increases the processing load for the sentence, possibly because the surface scope interpretation is considered first, and then revised, coherent with the Garden Path model (Frazier & Fodor 1978, among others). This latter hypothesis appears to be supported by self-paced reading studies (Tunstall, 1998; Anderson, 2004), which have shown that (5) and similar sentences are read significantly slower when interpreted on their inverse scope readings, an effect that is not mitigated by the presence of a supportive context. For this reason, we chose to examine *each* rather than *every*, as it is generally recognised as being more prone to take wide scope (Ioup, 1975; VanLehn, 1978; Fodor, 1982).

² We chose to test the *a-every* surface configuration rather than *every-a*, since on the *every-a* surface order (as in (i) below), it would not be possible to make the inverse scope reading (i-b) true while making the surface scope reading (i-a) false. Unlike the case in (7), given the entailment relation between the two readings in (i-a) and (i-b), we would not be able to find evidence for the inverse scope reading from participants' responses. See Footnote 4 for a notion of entailment in questions.

- (i) Did every doctor take a pencil?
- a. Is it true that, for each doctor, there is a pencil that s/he took? *Surface scope reading*
 - b. Is it true that there is some pencil such that every doctor took it? *Inverse scope reading*

3.1. Methodology

3.1.1. Participants

We tested 27 undergraduate students at Ulster University and 18 children (4;03 – 6;09, $M = 5;05$). All participants were native speakers of English. The data from three children were excluded from the analysis, as these children scored below 75% accuracy on control and filler items.

3.1.2. Materials and procedure

Participants were presented with an animated PowerPoint presentation on a laptop computer, depicting the content of the various stories, while an experimenter read the stories aloud to the participant. At the end of each story, participants would see a short video clip embedded in the PowerPoint presentation, showing a puppet asking the relevant question. The puppet was voiced by a native speaker of English, who had been instructed to record the questions with a neutral intonation.

At the beginning of the session, participants received a brief explanation of the task and they were asked whether they had any questions. The task began with four training items that were designed to familiarize participants with the task. Feedback was provided on these trials. Two of the training items were associated with *yes*-targets, and two with *no*-targets. Training items involved simple non-quantified questions, as in (8).

- (8) *Context story:* The bear and the dog are having a picnic. They want to eat the muffin, but there is only one. In the end, the dog decides to eat a cookie, so the bear eats the muffin.

Target question: Did the bear eat the muffin?

The main trials immediately followed the training items: each participant received four target trials, four controls, and four fillers, presented in one of two possible pseudo-randomized orders.

Target stories all followed the same basic structure. As inverse scope is generally hard to obtain for sentences containing an existential and a universal quantifier, the stories were designed to overcome this difficulty, making inverse scope as natural and easy to obtain as possible. For example, the story immediately introduced multiple characters, as having multiple entities already present in the mind of the speaker could make it easier to later refer the existential quantifier of the ambiguous sentence to more than one entity (Altmann & Steedman, 1988). Additionally, stories always featured two groups of characters, of which one engaged with the set of objects and the other did not, to contrastively focus the first. There is some evidence that having a second set of characters plays a role in making the inverse scope reading of sentences like (7) more acceptable (Kim, 2013). An example of a test story with its associated test question is provided in (9). In this story, the outcome is that the three doctors each take a different pencil. Participants should therefore give a *yes*-response only if they obtain the inverse scope interpretation of the target question, and a *no*-response otherwise.

- (9) *Context story:* The doctors and the nurses are looking for pencils to write with. They see some pencils on a desk. There is a green pencil, a blue pencil and a red pencil. Both the doctors and the nurses have a look at the pencils. The doctors get first choice, so they go to the desk first. One doctor takes the green pencil, another doctor takes the blue pencil. The third doctor takes the red pencil. The nurses don't take any pencils.

Target question: Did a doctor take each pencil?

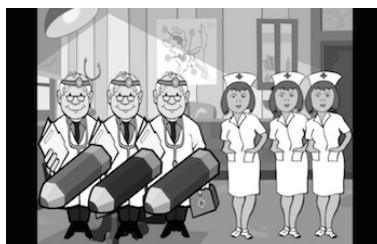


Figure 1: Example target item.

We also included four control items (two containing just the existential quantifier and two containing just the universal quantifier, with a *yes*- and a *no*-target for each) to ascertain that our participants had a general understanding of the relevant quantifiers in isolation, and moreover to make sure that our participants were able to give both *yes*- and *no*-answers. Control items were similar to targets, with one of the quantifiers replaced by a proper name; therefore the story featured either one agent performing an action on a set of three patients (*each* controls, as in (10) and the accompanying Figure 2) or a set of characters, one of which performed an action on a patient (*a* controls, as in (11) and the accompanying Figure 3).³

(10) **Each control** (*no-target*)

Context story: Anna is a doctor. She is going to visit some patients: a boy, a man and an old woman. Anna visits the boy and gives him some medicine. Then she visits the man and gives him the medicine too. However she realises that there is no time to visit the last patient, the old woman, so she doesn't visit the old woman and she has to leave.

Target question: Did Anna visit each patient?

(11) **A control** (*yes-target*)

Context story: Lucy goes to a restaurant. She is waiting for someone to come and speak to her. There are some waiters in the room. Finally, a waiter comes and greets Lucy.

Target question: Did a waiter greet Lucy?



Figure 2: Control item - *Each*



Figure 3: Control item - *A*

In addition to the targets and controls, four fillers were used to balance the overall number of *yes*- and *no*-responses. Like the training items, fillers did not contain any quantifiers. Each of the filler stories could be associated with one of two different questions, one which would elicit a *yes*-response and one which would elicit a *no*-response (see (12) for an example). The experimenter selected the appropriate target based on the participant's response to the immediately preceding target item.

(12) *Context story:* The zebra and the lion are walking through a garden, looking for their friend, the penguin, who is hiding. In the end, the zebra sees the penguin. The lion doesn't see him because he is behind the tree.

Yes-target: Did the zebra see the penguin?

No-target: Did the lion see the penguin?

³ Notice that in the controls for the indefinite, the quantifier is about a single individual, while in the target items it is about more than one individual, on the inverse scope interpretation. There is some evidence in the previous literature that, at least for sentences containing negation and a quantifier, inverse scope can be primed by letting the participant hear an unambiguous sentence containing the same elements. For example, participants who hear (i) show a higher acceptance rate for the inverse scope reading of (ii) (Viau et al., 2010).

(i) Not every spider hid behind the fence

(ii) Every spider didn't hide behind the fence

This phenomenon has recently been investigated for doubly quantified sentences as well (Kim, 2013), albeit with less clear results. Nevertheless, to avoid any possible influence of a priming effect, the *a*-controls were always the last items in both presentation orders.

3.2. Results

Both groups performed well on control and filler items, scoring above 92% accuracy on these trials. We found no difference between children and adults on controls and fillers (Wilcoxon-Mann-Whitney $W=242, p>.05$). Both groups were able to give both *yes*- and *no*-responses, and understood the meanings of the relevant quantifiers.

Moving on to performance on targets, children's and adults' rate of *yes*-answers (corresponding to inverse scope interpretations) is shown in Figure 4. A Mann-Whitney test revealed no significant difference between the two groups (Wilcoxon-Mann-Whitney $W=177.5, p>.05$). When giving *no*-responses, participants from both groups generally justified their responses by referring to the fact that there was no single individual who performed the relevant action (e.g., there was no single doctor who took all the pencils).

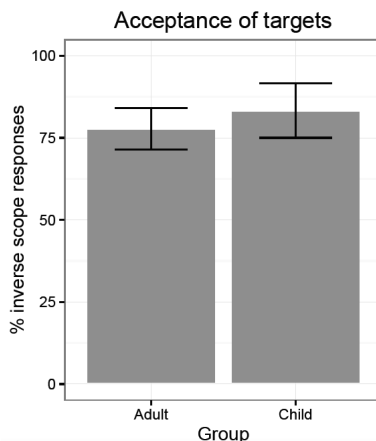


Figure 4: Percentage of inverse scope responses on targets.

3.2.1. Discussion

The prediction that we set out to test in our experiment was the following. Building on the QAR approach as formulated in Gualmini et al. (2008), children and adults should show no difference in accessing inverse scope readings for scopally ambiguous questions. This is based on two assumptions. First, children and adults only differ in how they handle and accommodate the QUD, and therefore they should be able to access inverse scope equally well in a situation where there simply is no QUD. Second, questions are not influenced by QUDs in the same way that declarative sentences are.

The prediction is confirmed by our results: we found no difference between children and adults in their interpretation of the target scopally ambiguous questions. The results are also in line with the view that children's failure to access inverse scope in certain previous experiments is likely not due to a deficiency in their grammars.

As we have previously mentioned, the QAR approach is meant to be a condition on declarative sentences, and one could formulate it as in (13). Formulated in this way, the QAR is silent about how scopally ambiguous questions should be interpreted.

- (13) **QAR:** The available interpretations of a scopally ambiguous sentence are those that entail an answer to the salient Question Under Discussion.

Our results are compatible with two hypotheses concerning the QAR and the interpretation of questions more generally. First, QUDs may only be relevant for the interpretation of scopally ambiguous declarative sentences; the interpretation of scopally ambiguous questions is driven by other factors. Under this hypothesis, the QAR can be maintained as it is. A second hypothesis is instead that QUDs also have an effect on the interpretation of questions, and we should seek to extend the QAR approach to incorporate

this. In the following, we outline this second hypothesis in more detail, and sketch a follow-up that could help us to distinguish between the two hypotheses.

3.3. Extending the QAR to questions?

In the theoretical literature, QUDs are not considered to be elements in isolation. Rather the discourse is conceived of as being organized as a set of QUDs that are ordered by entailment relations (Roberts, 1996; Büring, 2003; Aloni et al., 2007).⁴ More generally, the idea is that the discourse is organized as a game in which the ultimate goal for the interlocutors is to answer the main question – *What's the way things are?* (Roberts, 1996). Such a question is too broad to be answered at once, and for this reason it is broken down into smaller subquestions, which are easier for participants to manage. Answering a subquestion also provides a partial answer to its broader super questions, and in a similar way, answering a superquestion also answers anything below it. The immediate QUD in a given context is related to other broader questions that entail it. An example can be seen in (14).

- (14) Who ate what?
 a. What did Hilary eat?
 (i) Did Hilary eat bagels?
 (ii) Did Hilary eat tofu?

Given this set up, we could assume that a mechanism similar to the one that holds for declarative sentences is also at play here. That is, the available interpretations of ambiguous questions could only those that are entailed by the superquestion made relevant by the context. The QAR could then be extended to incorporate questions, as follows:

- (15) **Extended QAR**
 a. The available interpretations of a scopally ambiguous sentence are those that entail an answer to the salient Question Under Discussion.
 b. The available interpretations of a scopally ambiguous question are those that are entailed by their (immediate) superquestion.

This would mean that the interpretation of scopally ambiguous questions, like that of scopally ambiguous declaratives, is also driven by questions salient in the context. And this opens the door to potential differences between children and adults in the interpretation of scopally ambiguous questions.

How might this hypothesis be compatible with our results, given that we found no difference between the two groups? We could assume that our experimental story contexts made relevant a superquestion that entails the inverse scope interpretation of the target question. If so, children and adults would then be expected to have no problems accessing such an interpretation. For instance, in the doctor story described above in (9), we could assume that, since we were interested in knowing whether all pencils were taken by some doctor or another, the context generated the question (16), which is equivalent to, and therefore entails, the inverse scope interpretation of (17) in (17-b).

- (16) Is it true that for each pencil, there was a doctor who took it?
 (17) Did a doctor take each pencil?
 a. Is it true that there is a single doctor that took each pencil?
 b. Is it true that for each pencil, there was a doctor who took it?

In sum, the results of the experiment described above are compatible with an extension of the QAR to questions, and with the idea that the interpretation of questions is also influenced by salient (super)questions in the context. A follow-up directly manipulating the implicit superquestion in the context would allow us test this hypothesis. The idea would be to use two different contexts (18) associated with the same ambiguous question, such as the one in (19), with one of the contexts making relevant

⁴ Entailment between questions can be defined as follows (Roberts 1996, among others):

- (i) A question q_1 entails a question q_2 if and only if every proposition p that answers q_1 also answers q_2 .

a surface scope-biasing superquestion, (18-a), and the other making relevant an inverse scope-biasing superquestion, (18-b).

- (18) a. *Surface scope-biasing context:* The leader of the afterschool club hopes to find a boy who practices all sports: if there is a single boy who enters the football tournament, the basketball tournament, and the rugby tournament, he will give him a medal.
- b. *Inverse scope-biasing context:* The leader of the afterschool club hopes to run three tournaments: a football tournament, a basketball tournament, and a rugby tournament. He needs one more person to complete the teams, so he hopes that someone will join each one of the tournaments.
- (19) **Target question:** Did a boy enter each tournament?



Figure 5: The boys enter the sport tournaments

Here, the surface scope-biasing context (18-a) explicitly mentions that we are interested in finding out whether there is a *single individual* who joined all tournaments, thereby making salient the question *Is there a single individual who entered each tournament?* In contrast, the inverse scope context (18-b) (accompanying Figure 5), similar to the contexts used in the present study, puts the emphasis on whether some boy or other joined all the tournaments. It therefore makes salient the question *Is it true that for each tournament there is a boy who entered it?* If our intuitions are correct, (19) should lead to a *yes*-answer more frequently when presented in context (18-b). We are currently collecting data on this follow-up.

4. Conclusions

In the study reported in this paper we investigated the interpretation of scopally ambiguous questions by 4–6-year-old children and adults. Our main finding was that both children and adults had no problems accessing inverse scope interpretations of such questions. The results are in line with recent pragmatic approaches to the acquisition of scope ambiguity, which assume that children have the capacity to generate both surface and inverse scope interpretations of ambiguous sentences, sometimes differing from adults due to pragmatic factors, in particular due to their management of the understood Question Under Discussion (Gualmini et al., 2008). Considering more broadly the implications for QUD approaches and for the interpretation of questions, we have seen that the present results are compatible with two possible scenarios: either the QUD is not relevant for the interpretation for questions, or the QAR approach can be extended to questions, and our contexts made salient a super-question that facilitated inverse scope interpretations. Future work may aim to distinguish these two scenarios experimentally.

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