# Children Know the Prosody-Semantic/Pragmatic Link: Experimental Evidence from Rise-Fall-Rise and Scope


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**Abstract** Children's comprehension of scope interaction has received much attention especially since Musolino's (Universal grammar and the acquisition of semantic knowledge: An experimental investigation into the acquisition of quantifier-negation interaction in English, 1998) observation of isomorphism. Many studies report that English-speaking children prefer to assign the surface scope interpretations/isomorphic readings to sentences with multiple quantifiers or a quantifier and a logical operator, especially when there is no contextual support prior to a target sentence which would make one of the readings felicitous. Our set of experiments investigates whether children are sensitive to prosodic cues for scope assignment comparing a falling contour (i.e. neutral contour) and the Rise-Fall-Rise (RFR) contour, which in the literature has been argued to lead to the inverse scope interpretation (Jackendoff in Semantic interpretation in generative grammar. MIT Press, Cambridge, 1972; Büring in Linguist Philos 20: 175–194, 1997; Constant in Linguist Philos 35: 407–442, 2012; Contrastive topics: Meanings and realizations, 2014; a.o.). The results show that children are keenly sensitive to the difference between the two intonational patterns, and that they strongly associate the RFR contour with the inverse scope interpretation just like adults do.

**Keywords** L1 acquisition · Quantifier · Scope · Prosody · Intonation
Rise-Fall-Rise · Contrastive topic

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## 1 Introduction

For about twenty years, it has been noted in the acquisition literature that English-speaking children have a strong preference for the surface scope reading/isomorphic interpretation for sentences which contain a universal quantifier in the subject position and negation, as in (1).

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

a. No horse jumped over the fence. (∀>¬, surface scope reading)
b. It is not the case that all horses jumped over the fence. (¬>∀, inverse scope reading)

The interpretation of the sentence in (1) is ambiguous between the two readings described in (1a) and (1b). While English-speaking adults do not have difficulty interpreting (1) to mean (1b), English-speaking children tend to interpret (1) to mean (1a). The literature reports that the preference is robust; children reject the sentence (1) as a description of a situation where a proper subset of the horses (e.g. two out of three) jumped over the fence, 75–93% of the time (Musolino 1998; see also comparable conditions in Musolino et al. 2000; Musolino and Lidz 2006; and in Viau et al. 2010; a.o.). On the other hand, it has also been noted that children at the same age do not have difficulty accessing the LF of "Not > All" in sentences such as (2). They successfully accept the sentence as a description of a situation where the Smurf bought a proper subset of the oranges (e.g. one out of three), 85% of the time (Musolino et al. 2000).

(2) The Smurf didn't buy every orange.

This fact clearly indicates that what children have difficulty with is not the interpretation of "¬>∀" itself, but some mechanism to derive the interpretation from a sentence such as in (1). What would the mechanism be? In English, a standard analysis given to explain why the "Not > All" LF is available for (1) is that the universal quantifier in the subject position can reconstruct/undergo Quantifier Lowering (QL) to a position lower than the negation at LF (In the reconstruction view, it is generally assumed to be [Spec, vP]). In cases such as (2), the "Not > All" LF is less complex to derive; negation c-commands the object universal quantifier in the overt syntax, and thus there is no reconstruction/QL required to get the "Not > All" interpretation.[1] Musolino and colleagues argue that the phenomenon that children have a strong preference for the surface scope reading can be characterized as the Isomorphism-by-default (IBD) hypothesis, i.e., children prefer interpretations that are isomorphic to surface syntactic relations between the operators.[2]

[1] On the assumption that the lowest interpretable position for a quantifier in object position is below sentential negation.

[2] One of the other hypotheses that is discussed in the literature is the Question-Answer-Requirement hypothesis discussed by Gualmini et al. (2008). See Bajaj et al. (2014) for discussion on how much and when Question-Answer Requirement affects children's interpretation. It is also possible to propose that children have difficulty with reconstruction/QL (Sugawara and Wexler 2014).

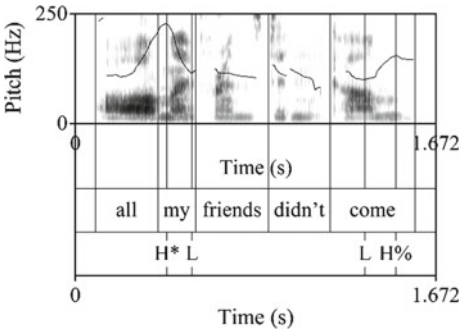


**Fig. 1** Pitch track generated by Praat using the sound file in Constant (2012 (46))

More recently, research has revealed that children do access the inverse scope reading under certain circumstances. Specifically, when children's processing load is alleviated by experimental manipulations, they seem to be more readily capable of accessing the "Not > All" LF (Musolino and Lidz 2006; Viau et al. 2010 to be reviewed in Sect. 3.1). In the current work, we take a different approach. We ask whether other manipulations can help children access the inverse scope reading. We study the effect of prosody on scope interactions, specifically a certain prosodic contour dubbed as Rise-Fall-Rise (RFR, most clearly described in Constant 2012; see Fig. 1). Sentences with this contour have the "Not > All" reading as a preferred reading.

The mechanism describing how the specific contour affects the interpretation will be reviewed in Sect. 2. The purpose of the experiment reported in this chapter is to test whether children are sensitive to this prosodic manipulation and if they are, whether they will interpret the sentences like adults do.

The structure of this chapter is as follows. In Sect. 2, the mechanism of RFR is summarized. In Sect. 3, we will review some of the recent acquisition work that shows that children can access the inverse scope interpretation to a much higher extent than previously thought.[3] We will also review recent experiments that look into an effect of certain prosody on scope interaction with adult participants. Our current study is reported in Sect. 4, and the discussion and conclusions are in Sect. 5.

## 2 Rise-Fall-Rise (RFR) Prosody

Let us closely look at what it takes to be the prosody to convey the "Not > All" interpretaion. Jackendoff (1972) proposes that the pitch accent on the universal quantifier and falling at the end together correspond to the "All > Not" reading, and that the pitch accent on the universal quantifier and rising at the end correspond to the "Not > All" reading.

[3]For more extensive review of the literature, see Musolino (2011).

(3) a. ALL the men didn't go.$_{L\%}$[4] (∀>¬)
b. ALL the men didn't go…$_{L\text{-}H\%}$ (¬>∀)

The contour that is associated with (3b) and Fig. 1 has been variously referred to as 'B-accent', 'Fall-Rise' etc. in the literature. However, following Constant, we would like to call it a Rise-Fall-Rise (RFR) contour, since the name is theory-neutral and it transparently describes the pitch tracks of the contour. Figure 1 shows the pitch track of a sentence "All my friends didn't come" with the RFR contour.[5] H* indicates a high tone with a pitch accent, and H% means high phrasal boundary tone. As we can see in the pitch track, there is a sharp rise with a stress (L+H*) on the universal quantifier and a boundary tone that is rising (L-H%) at the end of the (intonational) phrase (InP), which in this case (and in all of our experimental sentences) is sentence-final. As we will see shortly, the high tone with a pitch accent aligns with the Contrastive Topic of the sentence. In order to rise at the end, the pitch must "fall" after the initial rise. The final rise is at the phrase boundary—the RFR occurs entirely (stretched, if necessary) within one intonational phrase.

Büring (1997, 2003) discusses the effect of the Contrastive Topic contour on scope relations in German and English.[6] Based on his analysis, Constant (2012, 2014) analyzes the semantic consequences of the RFR contour.[7] Following Constant (2012), we assume that the RFR contour is not compatible with alternative dispelling foci and disambiguates away from interpretations that do not have an alternative proposition which remains unresolved. That is, the characteristics of RFR are decomposed into these steps—(i) The Rise-Fall on the Contrastive Topic activates its relevant alternatives, (ii) Alternative propositions are generated based on the alternatives activated in (i), (iii) For surface-ambiguous sentences multiple possible LFs and their alternatives are computed, and (iv) An LF is deemed viable if it satisfies the condition, attributed to the final rise, that there is at least one proposition in the set of its alternatives that is not yet resolved/dispelled after accepting the proposition expressed by that LF.

To illustrate, the example in (4–5) shows why the sentence in (4-B) under the RFR-contour is infelicitous: when pronounced with RFR, the alternative set in (5) is generated. RFR further requires that there should be unresolved or not-dispelled LFs remaining post assertion. However, the proposition expressed by "All my friends

[4]L and H stand for low and high tones, respectively. Boundary tones are indicated using the symbol %, e.g., low boundary tone as L%.

[5]The audio recordings of the examples in Constant (2012) are available at http://semanticsarchive.net/Archive/jhmYTI5M/.

[6]See Bobaljik and Wurmbrand (2012) for a different account concerning the effect of intonation, which makes use of the notion that "the special intonation represents a TOPIC >>FOCUS accent (Bobaljik and Wurmbrand 2012: 401)." Their account explains how the Information Structure, together with the special intonation that affects the IS, makes QR or reconstruction possible in an environment where QR or reconstruction is otherwise disallowed. We thank a reviewer for directing our attention to this point.

[7]In Constant (2012), RFR and CT are treated separately though he suggests that proposing a unified account of RFR and CT might be possible. Constant (2014) does not use the term RFR and instead calls it "lone CT," which is not accompanied by a Focus. In the current study, let us keep using the term RFR to cover the union of the phenomena.

liked it" entails the truth of all the other LFs in the alternative set. Hence no alternative proposition is still open for discussion and this violates the condition imposed by the final rise of the RFR-contour.

(4) A: Did your friends like the movie?
B: *[ALL]$_{CT}$ my friends liked it… (w/RFR contour)
(5) {all my friends liked it, some of my friends liked it, …}

Consider, by contrast, the example in (6–7). The utterance in (6-B) with RFR generates the alternative set described in (7). Note that the other LFs in the alternative set remain unresolved after asserting "John liked it." As a result, B in (6) is felicitous with RFR. Moreover, the utterance of B with RFR implicates (based on Gricean reasoning) that the speaker does not know the information about the other friends or that (s)he deliberately avoids mentioning the information about the others at this moment.

(6) A: Did your friends like the movie?
B: [JOHN]$_{CT}$ liked it… (w/RFR contour)
(7) {John liked it, Mary liked it, Fred liked it, …}

Finally let us turn to the case of the scope interactions between the universal quantifier and negation. The sentence "All my friends didn't come" is surface-ambiguous between the "All > Not" reading and the "Not > All" reading. If one entertains the interpretation of "All > Not," the set of alternatives to the LF that expresses that reading looks like the one in (9). However, once the sentence is asserted, these alternatives are dispelled since they are entailed by the assertion. This does not meet the condition of RFR that at least one alternative must remain unresolved after assertion. On the other hand, the set of alternatives for the "Not > All" interpretation of the sentence will be the one in (10). These alternative propositions are not entailed by the assertion and therefore they remain unresolved, which satisfies the condition of RFR. In other words, since only the inverse scope LF for (8-B) satisfies the condition of having unresolved alternatives, the sentence is disambiguated in favor of the "Not > All" reading when pronounced with RFR.[8]

(8) A: Did your friends like the movie?
B: [ALL]$_{CT}$ my friends didn't like it… (w/RFR contour)

| | | |
|---|---|---|
| (9) $\forall > \neg$: | Assertion | For all friends of mine, they did not like it. |
| | Alternatives | {For all friends of mine, they did not like it., For some friends of mine, they didn't like it ..} |
| (10) $\neg > \forall$: | Assertion | It is not that all friends of mine liked it. |
| | Alternatives | {It is not that all friends of mine liked it., It is not that some friends of mine liked it, ..} |

[8]Constant's account does not require there to be Focus in addition to Contrastive Topic in such sentences as B in (8). Büring's (1997) analysis on scope inversion in German can be understood in a similar manner but his analysis requires both Focus (on negation) and CT. For another approach where Focus does not have to be taken into account, see É Kiss and Gyuris (2003) for Hungarian scope inversion caused by a (fall-)rise intonation on CT. What attracts the (fall-)rise intonation in Hungarian is in the topic position, guaranteed by the discourse-configurational nature of Hungarian.

While the (Rise-)Fall-Rise contour and its impact on interpretation are fairly well understood, it is less widely discussed under what circumstances the contour is felicitously used; Given the nature of Contrastive Topic being a type of Topic, RFR is felicitous when the F-marked element (*ALL* in our examples) is already available, e.g. *given* in the Question under Discussion (QUD, see Roberts 1996/2012 and Buring 2003; a.o.). That is, the use of RFR is not felicitous in contexts like (11). Similarly, dialogues such as (12) where the CT is not *given* in the context, are less natural, while the conversation in (13) is perfectly natural, illustrating why RFR is most naturally uttered as an answer to a question raised by an interlocutor that contains the target of the CT accent in the RFR-answer.

(11) I am telling you how the party last night went. #ALL my friends didn't come… (with RFR)
(12) A: What happened at the party?
B: # ALL my friends didn't come… (with RFR)
(13) A: Hey, did (all) your friends come to the party?
B: ALL my friends didn't come… (with RFR)

To sum up the section, RFR is a general phenomenon in English that is not only found with quantified expressions (even though the interactions between RFR and scope relations have attracted most of the attention), and that the mechanism of interpreting sentences with a RFR contour requires that there be alternative proposition that remain unresolved at the post-assertion stage.

The point of the current study is to see whether children can access the inverse scope "Not > All" interpretation when read with the RFR contour, in a context where RFR is felicitously licensed.

## 3 Previous Studies

### *3.1 Children Can Access the Inverse Scope Reading*

Musolino and Lidz (2006) hypothesize that children do not interpret the sentence in (1) to mean "Not > All" because the children are somehow not ready for processing negative sentences under the "Not > All" reading out of the blue. Their Experiment 1 tested the set of conditions exemplified in (14). Condition 1 replicates the results reported in the previous literature and serves as the baseline for Condition 2. In Condition 2, an affirmative sentence precedes the target sentence, "in order to familiarize children with the intended domain of quantification (ibid: 825)."

(14) a. **Condition1**: Every horse didn't jump over the fence.
b. **Condition2**: Every horse jumped over the log, but every horse didn't jump over the fence.[9]

[9]They also tested the sentences that employed *and* instead of *but*. The results did not differ from each other.

They tested 10 five-year-old children with Condition 1 (mean age 5;7) and another 10 five-year-olds with Condition 2 (mean 5;2). The experiment is carried out as a Truth-Value Judgment task (Crain and Thornton 1998). All of the target sentences in the experiment had a universal quantifier *every NP* in the subject position followed by negation. The stories were constructed so that a proper subset of the objects have completed the action, i.e., "¬>∀ ∧ ∃" is made true in the story. The authors take the response "yes" to mean that the children access the "Not > All" interpretation, and the response "no" to mean that they access the "All > Not" interpretation. In Condition 1, children's "yes" rate was 15%, whereas in Condition 2, children's "yes" rate was 60%, which is significantly higher than in Condition 1. These results show that the children are, in fact, able to access the "Not > All" interpretation even when it is not isomorphic. They argue that, together with the results from their Experiment 2, what is lacking in children's linguistic system regarding this phenomenon is pragmatic abilities, and that under certain contextual manipulations such as using an affirmative sentence that would make the following negative sentence more felicitous, children's ability to accommodate the pragmatic considerations could be boosted. The idea is that "not p" is felicitous in a context where the possibility of p has been raised in the previous context.

Viau et al.'s (2010) Experiment 3 tests whether children could be "primed" by a certain interpretation. The two conditions in the experiment are illustrated in (15). Condition 1 serves as the baseline condition, where the six target sentences in the session have the same structure; a universal quantifier precedes the negation. In Condition 2, the target sentences in the first half of the session have "not" preceding the universal quantifier, and the target sentences in the last half of the session have the same structure as the sentences in the other condition. Since the isomorphic interpretation of the sentences in the first half is "Not > All," the first interpretation people will get with such a sentence is "Not > All."[10] That is, the subjects will be primed to access the LF of "Not > All" in the second half by the interpretation of the sentences in the first half of the session.

(15) a. **Condition 1**: [trials 1 through 6] Every horse didn't jump over the pig.
b. **Condition 2**: [trials 1 through 3] Not every horse jumped over the pig. [trials 4 through 6] Every horse didn't jump over the pig.[11]

[10]The "All > Not" interpretation is not contradictory to the sentence, although Viau et al. refers to this type of sentences as unambiguous test sentence. The "All > Not" interpretation is generally excluded because of the implicature computations (often called "indirect" scalar implicature).

[11]The authors do not discuss the issue of prosody. One wonders whether it is possible that in certain conditions the readers used RFR prosody, which is natural for a "Not > All" interpretation. Were the equivalent sentences in Condition 1 and Condition 2 (e.g. *Every horse didn't jump over the pig*) presented as exactly the same auditory taper, for example splicing in the tape from Condition 1 into Condition 2, to insure that prosody remained constant? Is it possible that some of the readers unconsciously used more RFR prosody in trials 4 through 6 in Condition 2 than in the trials in Condition 1? This would be natural given that the first 3 trials of Condition 2 involved *not every*, and this is quite natural to read with special prosody related to RFR. It would be really good to control prosodic effects in these studies, as we do in our experiment in this paper.

They tested 12 four-year-old children with Condition 1 and another 12 four-year-olds with Condition 2 on a Truth-Value Judgment Task (mean age of the 24 children = 4;6). The relevant stories support the situation where "$\neg > \forall \wedge \exists$" is made true, similarly to the experiment in Musolino and Lidz (2006). Therefore, children's "yes" responses indicate that they access the "Not > All" interpretation, and their "no" responses indicate that they access the "All > Not" interpretation. Viau et al. found in the baseline condition the "yes" rate for the first half to be 20% and for the second half to be 40%. On the other hand, the priming condition shows a higher rate of "yes" responses, over 80% both in the first half and in the last half of the session. Viau et al. report a significant difference between "yes" rates in the baseline condition and in the primed condition for the second half of items and conclude from this that children are capable of accessing the inverse scope "Not > All" interpretation, but that accessing it requires a bigger processing effort, which can, as shown in their experiment, be alleviated via priming of the relevant reading. In short, Viau et al. (2010) argue that children can access the non-isomorphic interpretation when the processing load is lessened.[12]

There is an alternative explanation, however, taking account of our observation in footnote 10 that the "All > Not" interpretation is actually not contradictory to the first sentence used in Condition 2: *Not every horse jumped over the pig*. It could be that no horse jumped over the pig. However this interpretation is in a typical contextual situation ruled out by a scalar implicature. One analysis might be that *not every* has *no* as an alternative. If *no* replaces *not every*, then the derived alternative *no horse jumped over the pig* implies the original sentence *not every horse jumped over the pig*. By the usual rules for deriving scalar implicatures, the implying (stronger) sentence is negated and conjoined to the original sentence. Thus *Not (No horse jumped over the pig)* is conjoined to *not every horse jumped over the pig*. This conjunction implies that there exists a horse that jumped over the pig. Under this implicature, "yes" is the only possible answer to the first 3 sentences of Condition 2. Note that this explanation assumes that children can compute implicatures, in conflict with much literature.

If the children do not compute the implicature in some cases, then *every horse didn't jump over the pig* (that is, the standard sentence type tested) is consistent with both a *yes* and a *no* response. The implicit assumption is that when a sentence is ambiguous for a child, that is, when either *yes* or *no* gives a true answer (one for each possible reading), then the child prefers to say *yes*.[13] However, this assumption

[12] It seems reasonable to us to explain the results of Musolino and Lidz (2006) along similar lines—rather than "introducing the relevant domain of quantification" their manipulation of having an affirmative sentence of the same form prior to the target sentence may make a Yes/No question of the sort *Did every horse VP*? salient. If, furthermore, questions are understood in terms of their answers, the negative answer to such a question *It is not the case that every horse VPed* could serve as prime for the non-isomorphic reading of the target sentence thus removing some of the processing load attached to inverse scope LF.

[13] See Meyer and Sauerland (2009) for discussion of the Principle of Charity, based on a careful examination of German sentences with focus particles. They propose the constraint called Truth Dominance to account for the bias to judge an ambiguous sentence as true.

seems to be tenuous as it holds only in some cases of the TVJT. See Crain and Wexler (1999) for discussion.

A related methodological issue is that we do not know how adults perform in these tasks. Viau et al. did not do any studies of adults. Since the results are probably affected by scalar implicature calculation, as we have just discussed, we do not really know what to expect by a fully competent speaker; calculation of implicatures is quite variable in a quantitative sense. Do speakers treat the different sentences (*Not every* vs. the "Not > All" reading of *every NP didn't*) differently when it comes to calculating the implicature?

The methodological conclusion is obvious: we learn more from experiments on these issues in which adults are tested as a separate group. We need a quantitative assessment of how adults behave in order to evaluate results from children. This is a lesson that has been learned in the study of scalar implicatures in general, and clearly applies to studies of quantifier scope. In the experiment reported in this paper, we include a separate adult group so that we can compare the children to such a group.

### *3.2 Adults Do Not Employ But Do Hear Different Contours*

Since Jespersen (1933), it has been noted that different prosodic contours (can) indicate different scope readings.[14] For such sentences where a universal quantifier and negation interact, Jackendoff (1972) points out that distinct prosodic patterns correspond to different scope relations. As we have seen in detail in Sect. 2, when a sentence is read with a sharp rise and fall on the universal quantifier and a sentence-final rise, the most salient interpretation of the sentence is "Not > All." Although there is a well-established literature on this phenomenon using off-line native speaker intuitions (Ladd 1980; Horn 1989, 2005; Krifka 1998; Büring 1997, 2003; Constant 2012, 2014 among many others; Gussenhoven 1983 and Ward and Hirschberg 1985 for counterarguments), there is little experimental work investigating under what conditions speakers use the RFR-contour and what effects it has on comprehension.

One study that looks into parents' child-directed speech is by McMahon et al. (2004). They report that parents do not differentiate prosodic patterns when reading to children. They also report that their adult participants showed no effect of intended interpretation [with distinct prosodic cues] in a comprehension study.[15]

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(i) Truth Dominance: Whenever an ambiguous sentence S is true in a situation on its most accessible reading, we must judge sentence S to be true in that situation. (Meyer and Sauerland 2009: 140)

[14] Jespersen pointed out that sentences with negation and a *because*-clause can have different scope relations depending on the prosody; *call* in (i) has a rising tone and *call* in (ii) has a falling tone.

(i) I didn't call because I wanted to see her (but I called her for some other reason).
(ii) I didn't call because I wanted to avoid her. (Jespersen 1933: 299)

[15] For more experimental studies to investigate the relations between contrastive prosody and interpretations, (see McDaniel and Maxfield (1992); Baauw et al. (2004); Braun (2006); Calhoun (2006).

Syrett et al. (2014b) report an adult comprehension study where their participants could access somewhat different scope interpretations when they are tested with a comprehension experiment. Their experimental items include 48 sentences. Among them 24 sentences are target items and 24 items are control items.[16]

The experimental procedure is as follows. A participant first sees the target sentence on a computer screen (e.g., "All the moms didn't allow eyeliner"). Then an auditory version of the sentence is played in one of two conditions, which were recorded as a part of a separate production experiment (Syrett et al. 2014a). In the production experiment, the target sentences were embedded in a story, and the intended meaning (e.g., whether "All > Not" or "Not > All") was cued by context. The comprehension experiment employed these two types of recordings, i.e., (i) recordings of naïve native speakers intended to convey "All > Not" and (ii) recordings intended to convey "Not > All." Then the participant sees a set of continuations which exemplify distinct scope relations such as in (16). Finally the participant is prompted to decide on which continuation fits better as an interpretation of the target sentence.

(16) All the moms didn't allow eyeliner
Continuation 1: They were all in agreement.
Continuation 2: Only the moms of older girls let their daughters wear it.

Syrett et al. report that when the sentence was read with the prosody that was uttered to convey the "All > Not" reading, the rate of choosing the intended continuation was 63.9%. When the sentence was read with the prosody to convey the "Not > All" reading, the rate of choosing the intended continuation was 66.2%.[17] These response rates were significantly above chance, though clearly did not indicate full disambiguation by contour. Based on these results, the study argues that comprehenders can exploit the difference in prosodic contours that are produced with the intention to convey different scopal interpretations.

This is a promising result suggesting that naïve adult English speakers arrive at the interpretations specified solely by intonation as the theoretical literature has maintained. However, given that the average correct response rates were only barely

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Part of McMahon et al. (2004) study looks into whether parents use contrastive prosody with ambiguous pronouns, and they show that the parents use suprasegmental cues to disambiguate the referents of pronouns.

[16]The target items consist of two kinds of sentences with *all … not* read with two different prosodic contours (2 * 2 = 4 items) read by four different speakers (4 * 4 = 16 items), and of one kind of sentence with *many/most … not* read with two different prosodic contours (1 * 2 = 2 items) read by four different speakers (2 * 4 = 8 items). This adds up to (16 + 8 =) 24 items. The auditory stimulus was presented three times to the participants. It follows that one participant hears the same sentence 24 times in one session, three repeated by four different speakers and two different prosodic patterns for each speaker.

[17]There was variation in the rates of participants' correct responses. For example, when speaker 1 utters the sentences with the prosody to convey the "Not > All" reading, the participants access the correct interpretation 83.0% of the time, while speaker 4 utters the sentences with the prosody to convey the "Not > All" reading, the correct response rate was 52.3%. These differences appear to be larger than the differences between interpretations for the two different prosodies overall.

above 60%, the effect appears weak and one might wonder whether experiment-specific and/or task-related factors prevented the connection between prosody and meaning from coming out more strongly. As we will see in Sect. 4, our experimental results show that the prosody-meaning relationship is indeed stronger than indicated by Syrett et al.'s results even for naïve speakers of English.

As mentioned above, the auditory stimuli were recorded as a part of a production experiment (Syrett et al. 2014a). That is, the speakers were not trained for the task nor were they instructed to produce those sentences for others to judge. Though the intended meaning (e.g., whether "All > Not" or "Not > All") was clearly cued by context, there is no guarantee that the speakers were actually attempting to produce a coherent utterance within a trial. In other words, they were not expected to read the sentences aloud so that others who are blind to the context governing the interpretations would get the intended interpretations. It is quite possible that this could have resulted in noisier, less crisp productions of intonation contours making them less reliable cues for comprehenders to disambiguate. Stimuli produced by a trained speaker, on the other hand, who are given specific instructions about the relevant contours might yield cleaner signals and thus may make it easier to isolate the consequences of a particular prosodic pattern for naïve comprehenders.[18]

Besides ensuring crisp production of the RFR contour there is also second factor, felicity in context, that should be considered when designing an experimental environment for investigating the extent to which naïve speakers are sensitive to prosodic contours when producing and comprehending scopally ambiguous sentences. Specifically, the prosody most strongly associated with the "Not > All" interpretation—"sharp rise and fall on the universal quantifier and rise at the end"—is most felicitous in a context where the number of individuals who VP*ed* is the larger question under discussion (e.g. How many moms allowed eyeliner?), as discussed in Sect. 2.[19] Recall, more specifically, from Büring (1997, 2003), Constant (2012, 2014) and also from the examples in Jackendoff (1972), that the "sharp rise and fall" part is taken to be an indicator of Contrastive Topic, which, in turn, is felicitous when it is *given* in the context and contrasted with some previous utterance, typically made by another interlocutor. The effect of the contrastive topic accent can be described as indicating that the larger question under discussion (*How many moms allowed eyeliner*?) is narrowed to a yes/no QUD, *Did all the moms allow eyeliner*? This is illustrated in (17), which has the two possible answers *Yes, all the moms allowed eyeliner* and *No, it is not the case that all the moms allowed eyeliner*. For a context that fails to provide this type of environment consider (18) taken from Syrett et al. in their production experiment and intended to elicit the RFR contour (Syrett et al. 2014a).

[18]There are two points of departure regarding this issue: trained versus naïve speakers, and instruction to pronounce the sentence with the intent to disambiguate via contour versus no such instruction. Which factor is more important is an important question, but we will leave it open.

[19]It is so if it concerns sentences where a quantified phrase is the Contrastive Topic of a sentence (Noah Constant, p.c.), just like the sentences we are entertaining. This is not necessarily the case with all sentences with Contrastive Topic.

(17) Q: So, what happened to the girls at the school dance party after all? Did their moms allow them to wear eyeliner?
A: Well, ALL the moms didn't allow eyeliner… Only the moms of the older girls did.

(18) *An example of their experimental item for "Not>All"*:
Several moms were helping their daughters get ready for the upcoming school dance. This is a progressive school, and moms are usually lenient about certain things, so even the younger girls thought their moms would approve of eyeliner. But at the dance only the older girls were wearing it. All the moms didn't allow eyeliner. Only the moms of the older girls let their daughters wear it.

In the scenario in (18), it seems to us that using RFR is actually not felicitous because the target sentence describes an entailment of the previous sentences (*Only the older girls were wearing eyeliner.)* and is not easily understood as contrasting with different options. Since the option of "All>Not" is already ruled out, the current QUD for the target sentence *All the moms didn't allow eyeliner* is thus not a yes/no question. Hence, the context does not fit the circumstances where RFR is most naturally licensed and so may have lead to speakers producing their utterances with less crisp intonation contours. Mindful of these considerations, our experiment will employ a dialogue format that will provide an appropriate QUD similar to the one in (17). This is a crucial difference in our experiment.

### *3.3 Testing Whether Children Know Prosody Interacts with Scope*

One of the earliest studies of children's command of sentence level intonation and in fact, to our knowledge, the only study that attempts to directly assess children's understanding of the impact of the RFR contour on interpretation is Ianucci and Dodd (1980). They conducted a picture-selection experiment with children ranged from K, Grades 2, 4, to 7 and with adults to test whether the difference in prosody leads to different interpretations.[20] Their experimental stimuli consisted of five sentences, each exemplifying different kinds of sentence types with quantifiers. The conditions that are relevant for our purpose are as follows.

(19) a. **Condition 1**: All the rabbits aren't in the cages. (Stress on *all*, rise at the end—i.e., "Rise-Fall-Rise")
b. **Condition 2**: All the rabbits aren't in the cages. (Fall at the end)
c. **Condition 3**: Not all the rabbits are in the cages.

The participants were told to help the experimenter create a picture book by selecting a picture that would go well with the stories. Their choice was between two pictures, one of which illustrates the "All>Not" situation, and the other the

[20]Thanks to Thomas Hun-tak Lee for referring us to this very relevant paper.

**Table 1** Part of results from Ianucci and Dodd (1980)

| Groups | Condition 1 | Condition 2 | Condition 3 |
|---|---|---|---|
| | Rates of Not > All (%) | Rates of Not > All (%) | Rates of Not > All (%) |
| K | 38 | 27 | 55 |
| Grade 2 | 47 | 19 | 79 |
| Grade 4 | 46 | 17 | 83 |
| Grade 7 | 58 | 18 | 100 |
| Adults | 96 | 18 | 100 |

"Not > All (& Some)" situation. They tested between 15 and 22 subjects per group. Their results are summarized in Table 1.

Children (and of course, adults) behave differently to Condition 1 and Condition 2. When the participants heard the prosody with falling tone at the end (Condition 2), they chose the "All > Not" pictures most of the time. On the other hand, when the participants heard the Rise-Fall-Rise prosody (Condition 1), adults chose the "Not > All" pictures most of the time, and the rates by children are between 38 and 58%. Given that the choices were among two options, the children chose the "All > Not" pictures 62–42% of the time. Though Ianucci and Dodd (1980) do not provide statistical analyses, the rates of choosing the "All > Not" pictures on Condition 1 seem to be consistently lower than that of Condition 2. It follows that the children regard the two kinds of prosody differently, although the connection between the Rise-Fall-Rise contour and the "Not > All" interpretation does not seem to be reliably built yet. It is also worth noting that in their experiment the rates of choosing the "Not > All" pictures in Condition 3 for preschoolers were as low as 55%. This shows that even when the isomorphic interpretation is "Not > All", the preschoolers in this experiment did not particularly prefer to choose "Not > All" pictures. As we have seen in Sect. 3.1, the children in Viau et al.'s experiment accepted the "Not > All" interpretation for sentences like in (8c) more than 80% of the time. Compared to that, it is possible that the children in Ianucci and Dodd's experiment had a stronger preference for the "All > Not" interpretation or that some experimental confound had prevented the children from accessing the "Not > All" interpretation when adults do so.

The study by Ianucci and Dodd is suggestive in that it shows that children regard the two types of prosody differently, and the preferences in interpretation are in the same direction as adults; with the Rise-Fall-Rise prosody, more "Not > All" interpretations are elicited. Moreover, the study obtains clear results for adults, strongly confirming linguists' intuitions regarding the effects of prosody. Our current study aims to follow-up on their study, with a more standardized procedure such as a wider variety of items, using recorded sound files by a trained speaker, and employing a dialogue which makes the prosody felicitous.

## 4 The Current Study

This study asks whether children know the effect of RFR on the scope assignment with universal quantifier and negation. This question is decomposed into two hypotheses.

(20) **Hypothesis 1**: If children are sensitive to the difference in contour, we expect different kinds of reactions to different contours (i.e., RFR contour and a neutral contour, to be discussed).
**Hypothesis2**: If children compute the effect of RFR in the same way as adults do, the rates of the "Not > All" reading will increase with the RFR contour.

The hypotheses might sound redundant, but hypothesis 1 is worth asking, given that the acquisition literature on contrastive stress has seen mixed results and it is a controversial topic whether children are sensitive to the difference in prosodic information (whether suprasegmental or not). It seems that results from previous studies using offline measurements support insensitivity to contrastive stress, while the results from studies using online method support sensitivity. For example, the pre-test experiments in McDaniel and Maxfield (1992) show that English-speaking children do not behave adult-like in an act-out task with sentences with contrastive stress.[21] Baauw et al. (2004) tested Spanish-speaking children and found that the rate of children's adult-like performance on the comprehension of the sentences with contrastive stress was around 44%, which was significantly lower than non-stressed sentences. On the other hand, using an eye-tracking method, Arnold (2008) report that four- and five-year-old English-speaking children showed the bias toward *given* objects with deaccentuation. Ito et al. (2012) also use an eye-tracking method and report that six-year-old Japanese-speaking children were able to make use of the contrastive stress to find the designated picture.

Though hypothesis 2 mentions adult reactions to RFR, there is still relatively little experimental evidence supporting the argument that (naïve) adult speakers will compute the effect of RFR and thus get the "Not > All" reading. The current study aims to add to the existing body of evidence (reviewed in previous sections) to assess the validity of claims in the theoretical literature about the effect of RFR.

[21] To be more specific, McDaniel and Maxfield (1992) tested children ranging from three to six years old, and examined children's sensitivity to contrastive stress with 10-scale scores. The average scores for each age group were the following: 4.7 for three year olds, 4.7 for four year olds, 5.8 for five year olds, and 6.7 for six year olds. McDaniel and Maxfield do not report how the individual data distributed, but it seems reasonable that three- and four-year-old children exhibit the chance performance, and the children in their experiment acquire some sensitivity to contrastive stress sometime during the time of five years old.

### *4.1 Method*

We conducted an elaborated version of the picture-selection task, where the picture-selecting phase is preceded by a short conversation between two people. We employed a dialogue in the stories since the RFR contour is most naturally elicited as an answer to a question. Figure 2 illustrates the experimental procedure for an item. The experiment was conducted using a PowerPoint slides on a laptop computer. The sound files were pre-recorded by a trained speaker and played to the subjects as the experimenter clicks to advance the story.[22] The first phase is an introduction of the story. The girl mentions objects in the story, and the boy says he is wondering what is going to happen to the objects. The second phase of the story shows four pictures on the computer screen. The four pictures describe situations where (i) All > Not (None of the objects VP-ed), (ii) Not > All (Some but not all of the objects VP-ed), (iii) All did (All of the objects VP-ed), and (iv) irrelevant situations are depicted. The positions of the pictures were randomized across trials. Shortly after the second phase is shown, the boy asks the girl a question to prompt the answer, and the girl utters a target sentence with either of the prosodic contours. The subjects were asked to point to the picture that they think she is in or she is talking about.[23] The timing of presenting stimuli was controlled manually so we could accommodate a possible request (especially from children) to repeat a trial.[24]

We crossed question type (Baseline-Question vs. Did-All-Question) and contour (Falling vs. RFR) with contour a between-subjects factor.[25] As we discussed in Sect. 2, we assume that the appropriate QUD (Did-All-Question) would make the utterance with RFR more felicitous than the question that does not license the RFR utterance (Baseline-Question). This assumption led to the two levels of the question-

[22] The female voice was recorded by the third author, an undergraduate research assistant familiar with the literature. The male voice was recorded by another undergraduate research assistant. Both of the speakers are native speakers of English. The recording took place in a sound proof booth.

[23] We asked participants to make choices, rather than leaving an alternative to answer "I don't know." A reviewer points out that it might have been interesting to provide this option as well. However, we suspect that while the choice "I don't know" could tell a lot if adults were tested, leaving the option available with child experiments would raise more complications because interpreting the "I don't know" answer is less straightforward (e.g., it could be due to parsing difficulty, the lack of grammar, being unwilling to answer, suggesting ambiguity, etc.).

[24] Since the experiment was run using an offline method such as a picture-selection task, we did not obtain reaction time data, which would have been interesting to analyze, as one of the reviewers pointed out. It is possible to manually collect timing data from the audio recordings of the sessions, but this is left for future research.

[25] We made contour a between-subjects factor after a pilot experiment that varied contour within subjects, produced an order effect suggesting that the effect of prosody carried over between sentences with different contours. Since this pilot study employed a different method from the current study (TVJT), it is not transparently comparable with the current study. The summary of the 6 children we tested is as follows: 3 were isomorphic for the most part, 2 were flexible (i.e., accepting both "Not > All" and "All > Not" situations most of the time), and 1 accepted "Not > All" and rejected "All > Not" for the RFR condition while accepted "All > Not" and rejected "Not > All" for the Falling condition.

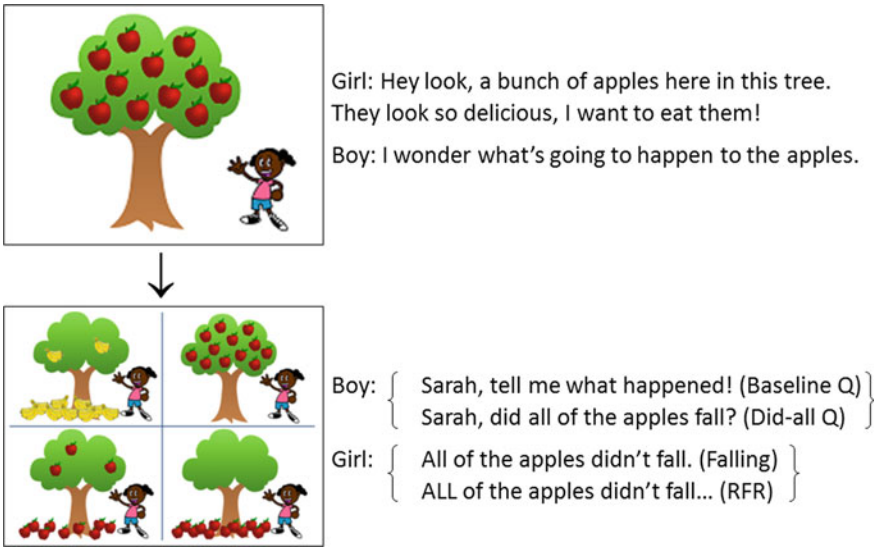



**Fig. 2** An example of the experimental procedure

type factor, and the expectations were that with the Did-All-Question condition the implicature calculation with RFR is more easily done, which would elicit more "Not > All" responses compared to the Baseline-Question condition. Figure 3 shows the minimal pair (Falling contour and RFR contour) of the pitch tracks from one of the experimental items. The experiment consists of 8 target items (4 with Baseline-Q and 4 with Did-All-Q) as well as 6 filler items. The list of the predicates used in the target items can be found in (21). The verbs we used are all intransitive and frequent in child corpus. The sentences in the filler trials were non-negated sentences, and two of the examples can be found in (22).

(21) The list of the predicates used in target sentences
break, dry, fall, fly, grow, open

(22) Two examples of filler items

a. All of the glasses broke. (basic simple past)
b. All of the helicopters did fly. (emphatic past)

Since the filler items are affirmative sentences, the participants have to pay attention to positive pictures as well as the "Not > All" and/or the "All > Not" pictures during the session. Moreover, three of the six filler items had "did" as in (22b). Because of this manipulation, the participants could not jump to an early conclusion upon hearing *did*, and instead they had to pay attention to the end of the sentence, to see whether a negation followed or not. The presentation order of the items was pseudo-randomized. We created two different sets of orders, and each participant was assigned randomly to either order of the items. When a child wanted to listen to

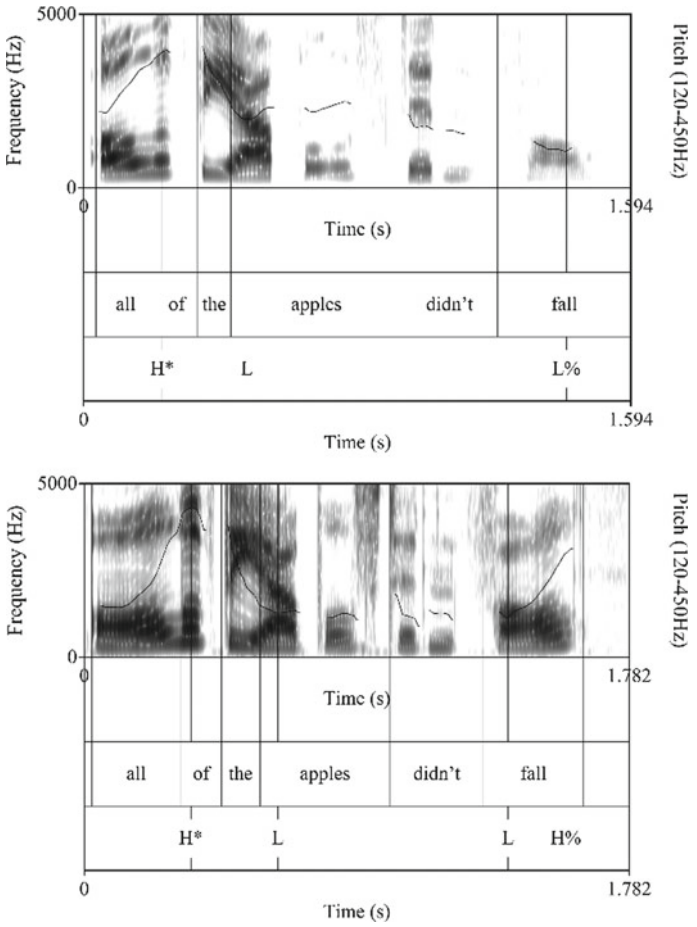



**Fig. 3** Pitch tracks for "All of the apples didn't fall" in the Falling condition (above) and the RFR condition (below)

the sentence again, the pair of the question and the answer got played. The session for each participant typically took about 10 min to complete. For adult participants, an answer sheet with 4 cells for each item was handed to them and they were asked to mark the answer.

We recruited 24 adult participants (12 on the Falling condition and 12 on the RFR condition) with no or little linguistics background. The participants were mostly undergraduate students either at MIT or at Wellesley College. For the experiment with children, we recruited 32 children. Among them, 16 were tested on the Falling condition (ranging from 4;4 to 6;10, mean age = 5;3) and 16 were tested on the RFR condition(ranging from 4;5 to 6;7, mean age = 5;2). The sessions took place at local daycare centers in Boston/Cambridge area and at the Boston Children's

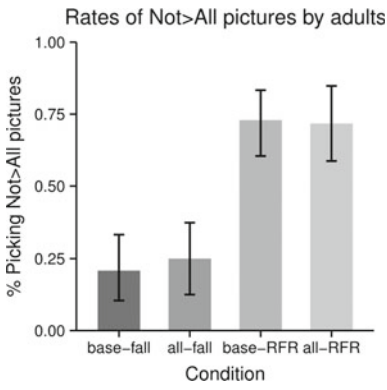



**Fig. 4** Results from adults—Error bars indicate 95% confidence interval

Museum across all socioeconomic and ethnic backgrounds. Additional 4 children were excluded from the analysis because they skipped two or more items (N = 3) or answered three or more fillers wrong (N = 1).

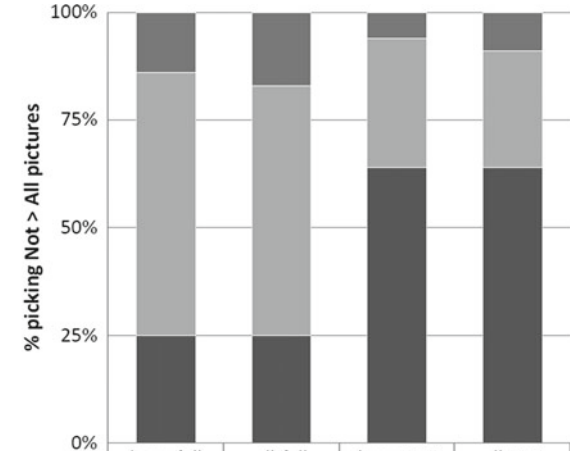
## *4.2 Results—Adults*

Of 192 relevant data points, 2 were excluded from the analysis since they contained responses that chose a positive picture. That is, the 190 data points are analyzed as values of a binomial variable. Figure 4 shows the rates of choosing the "Not > All" pictures. The rates of choosing the "Not > All" pictures for the Baseline-Q-Falling condition was 20.8%, for the All-Q-Falling condition was 25%, for the Baseline-Q-RFR condition was 72.9%, and for the All-Q-RFR condition was 71.7%. Using logit-LMEM,[26] statistical analysis of these rates reveals a main effect of contour (p = .036).[27]

[26]Since the maximally specified model did not converge, the order of the presentation was not considered as a possible factor here.

[27]The summary of the analysis of the fixed effects is as follows:

| | Estimate Std. | Error | z value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | −3.4466 | 2.0767 | −1.660 | 0.0970 . |
| contourRFR | 7.7889 | 3.7209 | 2.093 | 0.0363 * |
| qTypebase | 0.9689 | 1.5518 | 0.624 | 0.5324 |
| contourRFR:qTypebase | −2.3461 | 2.8214 | −0.832 | 0.4057 |




| | base-fall | all-fall | base-RFR | all-RFR |
|---|---|---|---|---|
| Incorrect | 0.14 | 0.17 | 0.06 | 0.09 |
| All>Not | 0.61 | 0.58 | 0.3 | 0.27 |
| Not>All | 0.25 | 0.25 | 0.64 | 0.64 |

**Fig. 5** Grand results from children

## *4.3 Results—Children*

Figure 5 displays all the responses from the child participants, including the errors (choosing positive pictures or irrelevant pictures). The errors account for 30 data points out of 256 data points, and the most frequent error was to choose the positive picture. The error rates were statistically not different across the four conditions.[28] The 30 error responses are excluded from the analysis hereafter. This allows us to treat the responses as binomial answers since the remaining data points only include responses either for the "Not > All" pictures or for the "All > Not" pictures.

The relative rates that only contain either "Not > All" or "All > Not" responses displayed in Fig. 6. It shows the rates of choosing the "Not > All" pictures by the conditions. The rates for the Baseline-Q-Falling condition was 29.1%, for the All-Q-Falling condition was 30.2%, for the Baseline-Q-RFR condition was 68.3%, and for the All-Q-RFR condition was 70.7%. Statistical analysis of these rates reveal a main effect of contour ($p = 0.038$).[29]

[28]The examination of the error rates across conditions using LMEM, where choices for positive ("All did") pictures and for irrelevant pictures were coded as errors and all other types of responses ("All > Not" and "Not > All") as relevant and hence non-errors, revealed no significant effect of condition.

[29]For the same reason as given in fn. 26, the order of the presentation was not considered as a possible factor. The question-type did not have an effect. The summary of the analysis of the fixed effects is as follows:

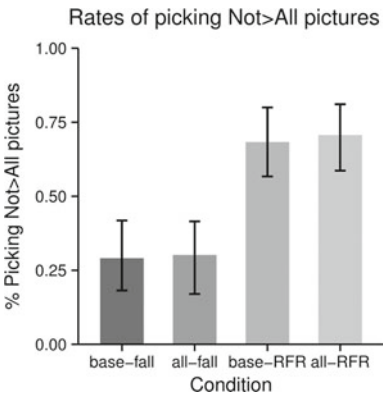



**Fig. 6** Normalized results from children—Error bars indicate 95% confidence interval

# 5 Discussion

## *5.1 Discussion—Adults*

The results from adults show that naïve speakers accessed the "Not > All" reading significantly more often when the sentence is read with the RFR contour. The finding supports the hypothesis that the "Not > All" interpretation is preferred with RFR. Another important thing to note is that in our experimental setting, the preceding context was always the same and neutral for the two conditions. Participants were not able to tell which picture to choose, until they heard the target sentence. The participants could arrive at the respective interpretations using only prosodic cues.

One might wonder why some of the adults did not get the "Not > All" reading even with RFR. It is possible that such participants were simply ignoring the specific contour and so failed to compute alternatives in the RFR condition. This may have been invited by the design because contour was a between-subjects factor hence exhibited no variation within a given participant to create a parallel experiment to the child study. An individual subject analysis shows that the "All > Not" responses under the RFR condition came from a small subset of the participants; one subject consistently (8 out of 8 items) picked "All > Not" pictures, and three subjects strongly preferred "All > Not" interpretations (6 or 7 out of 8). The other 8 subjects always (100%)

| | Estimate Std. | Error | z value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | −2.021 | 1.232 | −1.640 | 0.1009 |
| contourRFR | 3.480 | 1.678 | 2.074 | 0.0381 * |
| qTypebase | −1.814 | 1.622 | −1.119 | 0.2633 |
| contourRFR:qTypebase | 2.432 | 2.195 | 1.108 | 0.2679 |

picked "Not > All" pictures. The fact that some subjects kept choosing "All > Not" pictures even when the sentence was read with RFR suggests that those subjects have a strong preference when it comes to the sentences which contain a universal quantifier and negation, and it is possible that because of the strong preference they did not pay much attention to the prosody.

In sum, the results provide strong support for the idea that the prosody, specifically the RFR contour, leads a hearer to arrive at the "Not > All" interpretations in surface-ambiguous sentences with sentence level negation and a universal quantifier in subject position. Thus, building on Ianucci and Dodd's as well as Syrett et al. studies but employing a new methodology, our study provides further and stronger support for the claim that the choice of intonation (neutral or RFR) can disambiguate scopally ambiguous sentences.

## *5.2 Discussion—Children*

Results from child participants conform closely with those of adults. We have raised two questions to motivate this study—(i) Are children sensitive to the difference in prosodic contour? And (ii) if so, do children compute the effect of RFR in the same way as adults do? The results of this study suggest positive answers to both of these questions.

First, we observed a main effect of contour indicating that children are in fact sensitive to the difference in contours. This might come as a surprise since the literature is controversial as to whether children around the age of 4 and 6 are sensitive to sentential (suprasegmental) intonation, and studies of adult speech report that adults do not reliably produce distinctive contours to convey distinct scope relations (McMahon et al. 2004). Note that our set-up makes it difficult to explain this sensitivity as an experimental artifact. I.e., as shown in Fig. 2, the preceding stories up until the target sentences were the identical (using the same pictures and same sound files) across the conditions. Thus, the preceding stories did not favor one interpretation to other, and the only difference was the prosody of the target sentences. This suggests that children arrive at different interpretations solely depending on the difference in prosody. This seems to us to be quite strong evidence for children's knowledge of the scopal interpretation of prosody.

Second, the main effect of contour we observed was in the same direction as that for adults. This suggests that children compute the effect of RFR on sentence meaning in the way adults do. As we have seen in the Sect. 2, the computations involved determining the meaning of a sentence with RFR are rather complex involving comparing multiple LFs and their alternatives in terms of whether they satisfy the condition that after accepting the asserting under a particular LF at least one alternative to that LF must still be debatable. In spite of this complexity, children do seem to get the effect. This significantly contrasts with previous studies on the scope assignment by children. More specifically, we have reviewed two studies in Sect. 3.1 suggesting that children's inability to access the non-isomorphic interpretation in run of the mill

contexts is due to a processing limitation. That is, when the processing load is alleviated, e.g. by placing an affirmative sentence beforehand or by priming children with a certain LF, inverse scope readings become more accessible. Our results contrast with these studies in that children's ability to access the non-isomorphic reading increases without any manipulation to lessen the processing load. Rather, computing the effect of RFR might have put more processing load on children, since RFR involves alternative generation and implicature computation. One way to resolve this apparent conflict might be to suggest that our children were successful in computing the RFR effects because RFR induces strong enough pressures (e.g. by effectively eliminating the otherwise preferred reading prior to assessing whether it is true in the situation) in favor of inverse scope reading while previous studies leave the choice between the two readings open until situational fit (truth-value judgment or picture selection) has to be determined.[30]

Let us have a closer look at the RFR results of adults and those of children. At first sight, the figures look very similar—72.9 and 71.7% (mean by collapsing contours = 72.3%) with adults and 68.3 and 70.7% (mean = 69.5%) with children. As we discussed in Sect. 5.1, most of the "All > Not" responses from adults (about 28%) come from a subset of the participants. That is, there are several "isomorphism" participants whose responses contribute much of the "All > Not" responses in the RFR condition. When looking into the individual results of children, it turns out the 30% of the "All > Not" responses in the RFR condition are also coming from a subset of children, who could be dubbed an "isomorphic population." What is interesting is that the isomorphic children are found virtually only in the population younger than 5½ years of age. Figure 7 shows the correlation between the % of choosing "Not > All" pictures (out of 8 trials) on the RFR condition and children's age in days. In fact, the correlation was only marginal ($t = 1.78$, $df = 14$, $p = 0.097$, $cor = 0.429$) but we can observe that there is a trend with a medium-to-large effect size. As we can see in the graph, children can be grouped into two subgroups: the group who (almost) always get the effect of RFR, and the group who behave (almost) always isomorphic. Just as for adults, we observed two populations. The children look extremely like the adults in this regard; the percentages of isomorphic participants in fact is quite close for the child and adults populations. Children who almost always get the effect range from four years old to six, but the children who are almost always isomorphic can only be found in the population younger than 5½ years of age. One possibility is that the isomorphic group might undergo some kind of maturation in sensitivity to the prosodic contour that calls for computation over scopal alternatives. The other possibility, as mentioned previously, is that the maturation involves the

[30] An alternative approach might be to reduce the facilitation effects observed in previous studies to one of the factors we manipulated in our experiment as well. The natural candidate for such a proposal would be the salience of an appropriate question under discussion, as we suggested in footnote 12. Of course, details of such a proposal would need to be worked out.

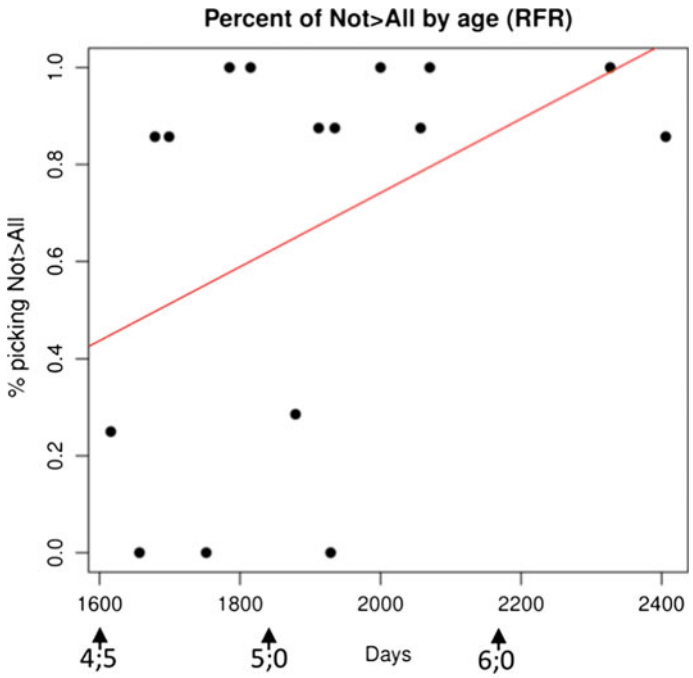



**Fig. 7** Correlation between % choosing "Not > All" pictures on the RFR condition and age

ability to compute scalar implicatures, or possibly to learn/construct the relevant set of alternatives for the scalar computation that forces the existence implicature.[31,32]

## 6 Concluding Remarks

In this chapter, we have presented a new set of data that shows that preschool children do access the non-isomorphic reading in sentences where a universal quantifier in the subject position precedes negation. Investigation on whether children can get the non-isomorphic reading in such sentences has gotten much attention since Musolino (1998), and several more recent studies have revealed that children have the competence in computing the interpretation, when the processing load is alleviated. The results of the current study add an important new data point to the literature showing that children do access the interpretation even when processing demands are likely

[31] See e.g. Reinhart (2006) for discussion of ideas along these lines.

[32] As one of the reviewers suggests, it would be interesting to look into a potential correlation between the sensitivity to the RFR contour (which affects the truth condition of a sentence, as in the current study) and the perception of prosody in general, which does not affect the truth condition of a sentence.

higher than in out of the blue cases. We have tested whether children are sensitive to the difference in prosody and compute the effects of the Rise-Fall-Rise contour. Our results show that children arrive at different interpretations solely depending on the difference in prosody, and that they interpret the sentences in the same direction as adults do, even roughly to the same quantitative extent as adults do and with roughly the same variability across subjects as for adults. This is a remarkable demonstration of child knowledge (and processing) being similar in many of the defining features as adult knowledge and processing. Children indeed know (and use) the prosody/alternative calculation link in a similar manner to adults.

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