# THE UNBEARABLE LIGHTNESS OF SCALAR IMPLICATURES

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**Abstract**

Research on child language inspired by the principles of the generative framework has aimed at showing mastery of various linguistic phenomena in young children. In an attempt to explain cases of late acquisition, child language researchers have pursued an explicit characterization of the extent to which child and adult language may differ. The present paper contributes to this line of research, by presenting the findings of several experimental investigations of young children's and adults' knowledge of scalar implicatures and downward entailment.

Scalar implicatures and downward entailment have received conspicuous attention in the linguistic literature, but these two phenomena have always been studied under different perspectives. In particular, previous research on scalar implicatures has focused on the conditions regulating the felicitous use of scalar expressions (e.g., the disjunction *or*), and has led to the formulation of the pragmatic norms that rule out the use of these expressions whenever a more informative term could be used (i.e., the conjunction *and*). This is the Gricean view of scalar implicatures. Recent research, however, has revealed a systematic correlation between downward entailment and scalar implicatures. In particular, it has been observed that scalar implicatures are cancelled in downward entailing linguistic environments. This observation has led Chierchia (2000) to an account of scalar implicatures which I call Semantic Core model. The Semantic Core model has received empirical support from psycholinguistic studies employing different experimental techniques. These experiments, though, have also revealed some differences in children's and adults' computation of scalar implicatures.

In this paper we report the findings of four experiments investigating English-speaking children's and adults' interpretation of scalar terms in the nuclear scope of the quantified expression *None of the Ns*. The results of two experiments investigating child language corroborate the findings from previous research in two ways. First, the findings provide more experimental evidence in favor of the Semantic Core model, showing yet another context in which scalar implicatures fail to arise, regardless of the amount of information available to the speaker. Second, the findings show that children's knowledge of downward entailment extends beyond the licensing and the interpretation of negative polarity items, and includes the logical properties of downward entailment. As for adults' computation of scalar implicatures, the results of two experiments investigating adults' interpretation of sentences containing the scalar term *and* in the scope of *None of the Ns* provide us with a context in which adults adhere to logic, in a way that closely resembles children's behavior reported in previous studies.

## Introduction

Research on child language inspired by the principles of the generative framework has aimed at showing mastery of various linguistic phenomena in young children. In an attempt to explain cases of late acquisition, child language researchers have pursued an explicit characterization of the extent to which child and adult language may differ. The present paper contributes to this line of research, by presenting the findings of several experimental investigations of young children's and adults' knowledge of scalar implicatures and downward entailment.

Scalar implicatures and downward entailment have received conspicuous attention in the linguistic literature, and these two phenomena have always been studied under different perspectives. The study of downward entailment has primarily focused on the role of entailment relationships in the licensing of negative polarity items (e.g., *any* in English). Previous research on scalar implicatures, by contrast, has focused on the conditions regulating the felicitous use of scalar expressions (e.g., the disjunction *or*), and has led to the formulation of the pragmatic norms that rule out the use of these expressions whenever a more informative term could be used (i.e., the conjunction *and*). This is the Gricean view of scalar implicatures. Recent research, however, has revealed a systematic correlation between downward entailment and scalar implicatures. In particular, it has been observed that scalar implicatures are cancelled in downward entailing linguistic environments (see Chierchia, 2000). For example, the pragmatic norms that favor *and* over *or* seem to be preempted (or reversed) in the same contexts in which *any* can occur. This observation has led Chierchia to an account of scalar implicatures, which I call Semantic Core model, that challenges the Gricean view. The Semantic Core model has received empirical support from psycholinguistic studies employing different experimental techniques. These experiments, though, have also revealed some differences in children's and adults' computation of scalar implicatures.

In this paper we report the findings of four experiments investigating English-speaking children's and adults' interpretation of scalar terms in the nuclear scope of the quantified expression *None of the Ns*. In particular, Experiment 1 was designed to determine whether scalar implicatures are cancelled in the nuclear scope of the quantified expression *None of the Ns*, by investigating children's accessibility of the inclusive-*or* interpretation of disjunction in this context. The same linguistic environment was investigated in Experiment 2, to determine children's knowledge of the logical properties of downward entailing environments. Experiments 3 and 4 are concerned with adults' computation of scalar implicatures, and compare adults' interpretation of the scalar terms *and* and *or* in the scope of the quantified expression *None of the*

*Ns*. The purpose of these experiments is to determine the extent to which adults reject a sentence that is logically true, exclusively on the grounds that an alternative and more informative statement is available to the speaker.

## 1 Scalar Implicatures and Downward Entailment

### 1. 1 The Gricean View of Scalar Implicatures

The felicity conditions on language use have received considerable attention since Grice's seminal work, and the interpretation of sentences containing scalar terms is one of the most-studied phenomena (see Gazdar, 1979; Grice, 1975; Horn, 1972, 1989; Levinson, 1983; Sperber and Wilson, 1986).[1] In this section, we review the basic principles of pragmatics, and we illustrate how they account for the interpretation of sentences containing logical words, including the disjunction operator *or*, and determiners like *a* and *some*.

The most basic principle of pragmatics is Grice's Cooperative Principle, stated in (1):

(1) "Make your conversational contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged."[2]

The principle of cooperation is articulated into a number of conversational maxims. For the present purposes, particularly important are the two maxims of Quantity:

(2) 1. Make your conversational contribution as informative as is required.
2. Do not make your contribution more informative than is required.

To illustrate, let us consider how these principles account for the interpretation of sentences containing the English indefinite article *a*. Consider (3).[3]

(3) Mary has a child.

[1] Children's knowledge of pragmatic norms has not received the same attention, with the exception of some studies investigating children's interpretation of logical connectives. We will discuss the results of these studies in section 2.1.
[2] Grice (1989; p. 26).
[3] This example is illustrated in Chierchia and McConnell-Ginet (1990; 2000), to which we refer the reader for an informal discussion of conversational implicatures.

The most natural interpretation of the sentence in (3) is that Mary has exactly one child, and adult speakers of English judge the sentence (3) infelicitous if Mary has more than one child. For example, if it is part of the speaker's conversational background that Mary has three children, adult speakers object to (3) on the grounds that (4) constitutes a more accurate description.

(4) Mary has <u>three</u> children.[4]

Let us spell out the reasoning behind the infelicity of (3) in more detail. Encountering (3), the hearer assumes that the speaker is obeying the Principle of Cooperation, and is conveying his knowledge as cooperatively as possible. In uttering (3), however, the speaker does not commit to the proposition in (4); this sentence was a possible alternative statement, and should have been used, if the speaker had reason to believe that Mary has three children. Assuming that the speaker has accurate knowledge of the situation he is describing and that he intends to convey his information in a cooperative way, the hearer will therefore infer that the speaker has no reason to believe that Mary has three children. As a consequence, upon hearing (3), one infers that the speaker had reason not to use (4). In short, (3) is interpreted as meaning that Mary has a child, but also that she does not have three of them.[5] This leads adults to reject the sentence *Mary has a child*, as an accurate description of a situation in which (4) is known to be true.

It is important to notice that the reasoning above does not follow from semantic principles alone. For the present purposes, we can view the semantic contribution of the indefinite article as an existential quantifier.[6] If we adopt this view, the semantic component of the grammar specifies that (3) is true if Mary has at least one children. The *exactly one* interpretation of the indefinite article is due to the application of conversational maxims, as a result of the reasoning presented above. In order to distinguish between the semantic contribution of the indefinite article and the implicature associated with it , one can observe that only the latter can be cancelled. In other words, the speaker can add a qualification to (3), which defeats the implicature associated with the indefinite article (e.g., *Mary has a child. In fact she might have more than one*), whereas the speaker cannot

[4] Throughout the paper, we will underline the expression, or pair of expressions, that exemplifies the contrast under consideration. Such convention is only intended to help the reader, and is not to be interpreted as a particular intonation.

[5] Obviously, the reasoning above could be repeated for any numeral.

[6] The quantificational force of determiner phrases headed by an indefinite has received considerable attention in the literature (see Carlson, 1977). In particular, it has been observed that in generic contexts the correct interpretation of indefinite noun phrases involves a universal quantifier (e.g., *A poddle gives live birth*). In our discussion of the indefinite article, however, we will not consider generic uses, and we will focus on cases in which the existential quantifier specifies the correct truth-conditions of the sentence under consideration.

question the truth-conditions associated with the indefinite article, (e.g., the sentence *Mary has a child. In fact she does not have any* is a contradiction). We will discuss the defeasibility of pragmatic norms momentarily.

The relevance of conversational maxims extends beyond cases in which an alternative description of the context under consideration results from the choice of a different term (e.g., *a* vs. *three*). Sentences containing the disjunction operator *or* provide an example of this phenomenon. Suppose the speaker knows that John went to the store and wants to describe what John bought. Regardless of what John bought, (5) is not a felicitous description.

(5) John bought chips or ice cream.

We can explain why such sentence is infelicitous through a reasoning similar to the one described for (3).[7] The speaker is assumed to convey his knowledge about what John bought in the most cooperative way. Therefore, the speaker should use one of the statements in (6), depending on which one is true in the particular context under consideration.

(6) a. John bought chips.
b. John bought ice cream.
c. John bought chips and ice cream.

The expectation that the speaker's contribution to the conversation is maximally informative makes (5) infelicitous in any of the circumstances described by the sentences in (6). If the speaker knows that John only bought chips or if the speaker knows that John only bought ice cream, the sentences in (6a) and (6b) would constitute a better way to communicate such knowledge, even if they do not have the same structure as (5). For the purposes of the current study, however, we will be exclusively concerned with cases in which an alternative (structurally identical) representation is readily available to the speaker.

Let us focus on a situation in which John bought both chips and ice cream. If the speaker knows that John bought both chips and ice cream, then the maxim of quantity favors the use of (6c), which conveys the information available to the

[7] The felicity of (5) improves if the speaker further qualifies his statement. For example, consider the sentences in (i).

(i) a. John bought chips or ice cream, but I am not going to tell you which.
b. John bought chips or ice cream, but I do not exactly remember which of the two.

It is important to observe, however, that in both cases the speaker's qualification communicates to the hearer that the speaker does not intend to, or simply cannot, be cooperative. Again, we will consider the cancellation of scalar implicatures shortly.

speaker in a more cooperative manner. Since the speaker did not use (6c), the hearer of (5) is invited to assume that the evidence available to the speaker did not support such statement. Consequently, upon hearing (5), the hearer will assume that the speaker does not believe (6c) to be true. As a result, the disjunction operator in (5) is interpreted according to the truth conditions associated with exclusive-*or*.[8] In short, (5) is interpreted as meaning *John bought chips or ice cream, but not both.*

The maxim of quantity described in the paragraphs above explains why sentences containing the disjunction operator are infelicitous when the corresponding sentence containing *and* is true. A similar behavior is shown by other linguistic expressions, such as quantifiers (e.g., *some* vs. *every*), gradable adjectives (e.g., *beautiful* vs. *wonderful*) and numerals (e.g., *three* vs. *a*). A unifying account of these expressions has been provided by Horn (1972). Horn (1972) observed that the set of circumstances that verify *S(A and B)* is a subset of the circumstances that verify *S(A or B)*.[9] Because of the subset/superset relation that holds between statements with *or* and the corresponding statements with *and*, the logical words *or* and *and* can be seen as constituting a scale. If both *S(A)* and *S(B)* are true, therefore, a sentence of the form *S(A and B)* is favored by the Maxim of Quantity because it is true in a narrower set of situations and, therefore, more informative. Intuitively, the maxim of quantity places an utterance against a set of alternative statements that differ in the amount of information that they convey, because of the particular scalar term they contain. For example, consider the disjunction and conjunction operators. A sentence of the form *S(A or B)* is consistent with a set of possibilities that are ruled out by *S(A and B)*, but these possibilities are irrelevant when it is known that both *S(A)* and *S(B)* are true. The same reasoning applies to other scalar items, for example, quantifiers

[8] It may be helpful to compare the following truth-tables.

| A | B | A or B (inclusive-*or*) | A or B (exclusive-*or*) | A and B |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 |
| 1 | 1 | 1 | 0 | 1 |

[9] We use the notation *S(A conj B)* to refer to any sentence that contains a coordinate phrase. Although we will be mainly concerned with cases of coordination between NPs in object position, it will be always possible to generalize our reasoning to cases of coordination between verbal phrases or sentences. For the present purposes, this notational convention is meant to help the reader in constructing the relevant example.

(*every* ⊆ *most* ⊆ *many* ⊆ *some*) or numeral adjectives (.. *ten* ⊆ *one* ⊆ *a*).[10] Adopting this representation of scalar terms, for any terms $\boldsymbol{a}$ and $\boldsymbol{b}$ such that $S(\boldsymbol{b}) \subseteq S(\boldsymbol{a})$, the Maxim of Quantity favors the use of $S(\boldsymbol{b})$, and the interpretation of $S(\boldsymbol{a})$ will be accompanied by an implicature of the form *not* $S(\boldsymbol{b})$.[11] This implicature accounts for the infelicity of $S(\boldsymbol{a})$ in contexts in which the speaker could have used $S(\boldsymbol{b})$. Implicatures that are constructed according to this scheme are commonly labeled as scalar implicatures.[12]

It is important to observe that the implicature described above rests upon the assumption that the speaker has extensive knowledge of the context he is describing. When the hearer has reasons to doubt that the speaker's knowledge is

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[10] Again, the subset/superset relationship does not hold for scalar terms. The subset/superset relationship holds between the evaluation of sentences that differ only with respect to the scalar term that occurs in them. For example, the sentence in (ia) is true in a subset of the circumstances in which (ib) is true, and (ib) is true in a subset of the circumstances in which (ic) is true.

(i) a. Every student wrote a paper.
b. Most students wrote a paper.
c. Some student wrote a paper.

For the purposes of the exposition we will order scalar terms on the basis of the subset/superset relationship that holds between sentences that contain such scalar terms.

[11] We can now modify the 'label' of the truths-tables to show that it derives from one connective and the negation of the other.

| A | B | A or B | A or B and not (A and B) | A and B |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 |
| 1 | 1 | 1 | 0 | 1 |

[12] In the remainder of the paper we will refer to the interpretation of a sentence that does not take into account scalar implicatures as the 'basic' or 'logical' interpretation, and to the interpretation that takes into account the implicature as the 'derived' interpretation. It is important to stress that this does not mean we are assuming that sentences containing a scalar term are ambiguous, since one interpretation is explicitly derived from the other. The claim that sentences containing scalar terms are ambiguous is untenable. For example, consider a sentence like *Some students wrote a paper*. If we admit that such sentence is ambiguous between the two interpretations in (i), then on the reading in (ib) the interpretation of the determiner *some* violates the putative linguistic universal that all determiners are conservative (see Chierchia and McConnell-Ginet, 1990; 2000).

(i) a. Some and possibly all students wrote a paper.
b. Some but not all students wrote a paper.

complete, however, scalar implicatures do not arise. Consider the disjunction operator. If the speaker expresses an expectation or a prediction about what John will buy, the use of disjunction is felicitous. Consider (7). Clearly, this sentence does not imply that the speaker is excluding the possibility that John will buy both chips and ice cream.

(7) John has gone to the store. I'll bet you $5 he will buy chips or ice cream.

In the example above, the disjunction can be interpreted as inclusive-*or*, and (7) is not interpreted as *John has gone to the store. I'll bet you $5 he will buy chips or ice cream, but not both.* In other words, the possibility that John will buy both chips and ice cream is consistent with the prediction in (7). Of course, the speaker could restrict the range of situations that he considers likely to happen (e.g., saying *I'll bet you $5 he will buy chips or ice cream, but I am sure he will not buy both*). The possibility that John will buy both chips and ice cream, however, is not excluded because of the meaning of (7), nor is it excluded because of an implicature triggered by the use of *or*.

Comparing the interpretation of (5) and (7), we are led to conclude that the amount of information available to the speaker distinguishes between a description of an event that has already taken place, and a prediction about what will happen. In a situation of uncertainty, such as when one makes a prediction or a bet, a speaker who chose any of the sentences in (8) would end up excluding some of the alternatives that are consistent with his conversational background. Therefore, if the speaker chose any of the sentences in (8), his contribution would not be completely supported by the evidence available to him.

(8) a. John has gone to the store. I'll bet you $5 he will buy chips.
b. John has gone to the store. I'll bet you $5 he will buy ice cream.
c. John has gone to the store. I'll bet you $5 he will buy chips and ice cream.

The study of the conditions regulating the interpretation of terms like the disjunction operator and the indefinite article has led to the current view of scalar implicatures. On this view, principles of pragmatics influence the interpretation of scalar terms in ordinary contexts, 'selecting' a subset of the alternatives licensed by the principles of semantics. In contexts of uncertainty, however, scalar implicatures fail to arise, and the full range of truth-conditions licensed by the semantics is available to the hearer.

It is worth observing that the neo-Gricean view of scalar implicatures can be incorporated into a specific model of the interaction between different modules

of the grammar.[13] In particular, the neo-Gricean view of scalar implicatures is consistent with an independently justified model of language processing, called the Modularity Matching model (see Crain and Thornton, 1998; Crain and Wexler, 1999). The Modularity Matching model maintains that the different modules of the grammar are hierarchically organized, such that operations of higher level components apply to the output of lower level components. If multiple outputs are transferred from one level to another, principles at higher levels will select among the outputs from the lower level. Crucially, if a single output is transferred from one level to another, principles at the higher level will be preempted. We can refer to the principles that decide among multiple inputs as 'pruning principles' to distinguish them from structure-building operations. Pruning principles of the semantic component eliminate some of the outputs licensed from the syntactic component. For example, Crain and Steedman (1985) spelled out these modular assumptions relatively to the syntax/semantics interface, and argued that "syntax proposes and semantics disposes." An extension of this model to the semantics/pragmatics interface has been proposed by Crain, Gualmini and Meroni (2000) and Gualmini, Meroni and Crain (2001). According to these researchers, the interaction between semantic and pragmatic principles is subject to the same modularity assumptions, such that "semantics proposes and pragmatics disposes." This modular architecture explains how the interpretation of scalar terms comes about when sentences are subject to conversational implicatures. From this perspective, conversational implicatures are pruning principles of the pragmatic component, and eliminate some of the alternatives licensed by the semantic component.

To recap, the neo-Gricean view of scalar implicatures provides an explicit characterization of the interpretation of scalar terms in ordinary conversational contexts. Importantly, under the neo-Gricean view, scalar implicatures fail to arise when the hearer knows the speaker does not have accurate knowledge of the situation being described. Under this view, scalar implicatures are conceived as principle of pragmatics that constrain the interpretation of a sentence, after the semantic module has provided an interpretation for such sentence. The modular architecture implicit in the neo-Gricean view, however, has been questioned on the basis of linguistic contexts in which scalar implicatures fail to arise, in spite of the speaker's accurate knowledge of the situation being described (e.g., Chierchia, 2000; Chierchia, Crain, Guasti, Gualmini and Meroni, 2001). In the next section we illustrate such contexts.

[13] With the term 'neo-Gricean', we will refer to the line of research which developed Grice's intuitions which showed how a derived interpretation can be systematically constructed for each scalar term (see Horn, 1972; Gazdar, 1979).

## 1.2 A Puzzle for the neo-Gricean view

The previous section outlined the basic principles of the neo-Gricean view of scalar implicatures. We observed that such a view maintains that scalar implicatures fail to arise if the speaker does not have extensive information about the situation under consideration. By contrast, the neo-Gricean view points to the accuracy of the information available to the speaker as one of the prerequisites for scalar implicatures to arise. This view, which draws upon a modular conception of the semantics/pragmatics interface, has been challenged by Chierchia (2000). In particular, Chierchia (2000) observes that the neo-Gricean view fails to explain why scalar implicatures do not arise in a variety of linguistic contexts, which cannot be described as contexts of uncertainty (also see Chierchia, Crain, Guasti, Gualmini and Meroni, 2001).

Let us review some of the contexts discussed by Chierchia (2000). Consider the examples in (9). In all such sentences, the implicature of exclusivity for the disjunction operator fails to arise, such that *or* is interpreted under its inclusive-*or* reading.

(9) a. John did not write a paper or make a presentation.
b. None of the students wrote a paper or made a presentation.
c. None of the students who wrote a paper or made a presentation received a good grade.
d. John fulfilled the requirements of the Syntax seminar without writing a paper or making a presentation.
e. John graduated before he wrote a paper or made a presentation.

Consider (9a). By uttering (9a), the speaker excludes three kinds of situations: (i) John did not write a paper, but he made a presentation; (ii) John wrote a paper, but did not make a presentation; and (iii) John wrote a paper and made a presentation. Let us consider (iii). The possibility that John did both is excluded by (9a), as shown by the fact that one cannot continue the sentence in (9a) as in (10).

(10) #John did not write a paper or make a presentation. He did both.[14]

Intuitively, the infelicity of (10) is due to the fact that the only set of circumstances that verifies the sentence *He did both* is disjoint from the set of circumstances that verify *John did not write a paper or made a presentation*. If the disjunction operator received an exclusive-*or* interpretation, the possibility

[14] We will ignore the cases of meta-linguistic negation discussed by Horn (1972; 1989).

that John did both would not be excluded. A similar reasoning can be applied to all the contexts in (9).

As an additional example consider (9e). By saying *John graduated before he wrote a paper or made a presentation*, the speaker excludes three sets of circumstances: (i) John made a presentation before he graduated; (ii) John wrote a paper before he graduated; and (iii) John wrote a paper and made a presentation before he graduated. Importantly, if the inclusive-*or* interpretation of disjunction was affected by the implicature of exclusivity, it could not be explained why (9e) excludes that John had to write a paper and make a presentation before he could graduate. But this possibility is excluded, as shown by the infelicity of (11).

(11) #John graduated before he wrote a paper or made a presentation, but not before he did both.

It is important to observe the following contrast: the implicature associated with the disjunction operator *or* arises if the disjunction operator occurs within a clause introduced by the temporal adverb *after*. Consider (12), which contrasts with (9e).

(12) John graduated after he wrote a paper or made a presentation.

Intuitively (12) presents the same infelicity as *John bought chips or ice cream*. In particular, (12) suggests that John did not both write a paper and make a presentation, as suggested by the felicity of (13).

(13) John graduated after he wrote a paper or made a presentation, but not after he did both.

The existence of linguistic environments with related meanings which differ in the raising of the implicature plays a crucial role in the account of scalar implicatures proposed by Chierchia (2000). We will return to the contrast between expressions with related meanings in next section.

It is important to stress that the availability of the full range of truth-conditions associated with inclusive-*or* in the examples above does not depend on the conversational context. As we have observed, the neo-Gricean view maintains that in contexts of uncertainty the speaker does not have extensive knowledge of the situation being described, and the computation of scalar implicatures would make unavailable a set of alternatives that are consistent with the speaker's background. All the sentences in (9) constitute a description of an event that has already taken place, however. The speaker is reporting a fact. According to the neo-Gricean view of scalar implicatures, scalar implicatures should arise, and

influence the interpretation of the disjunction operator. Nonetheless, scalar implicatures fail to arise in the linguistic contexts in (9).

The existence of linguistic contexts in which scalar implicatures fail to arise constitutes a puzzle for the neo-Gricean view. The puzzle is further complicated by the fact that all such contexts share a second property, for which pragmatic principles are not immediately relevant: the contexts in (9) license the English word *any*. Consider the examples in (14).

(14) a. John did not write any paper.
b. None of the students wrote any paper.
c. None of the students who wrote any paper received a good grade.
d. John graduated without writing any paper.
e. John graduated before he wrote any paper.

The licensing of the word *any* has traditionally pertained to the semantic properties of some linguistic environments, namely the pattern of entailment generated by these environments.[15] Assuming this informal characterization of the contexts that license negative polarity items, it needs to be explained why scalar implicatures do not arise in ordinary conversational contexts, if a scalar term occurs in a downward entailing context. The observation that scalar implicatures are cancelled in downward entailing context is due to Horn (1989), but a first explanation of the relationship between scalar implicatures and downward entailment has only been proposed by Chierchia (2000). This account has been called the Semantic Core model by Chierchia et al. (2001). The main innovation of the Semantic Core model with respect to the neo-Gricean view is constituted by the claim that the computation of scalar implicatures is subject to a constraint. In particular, SIs must lead to a more informative interpretation of the sentence under consideration than its basic interpretation. As we will see in section 1.4, the technical apparatus proposed by Chierchia (2000) draws upon the notion of information strength proposed by Kadmon and Landman (1993), which is based on the entailment relationships between alternative statements. Since the notion of downward entailment plays a crucial role in the Semantic Core model, it is important to describe the main properties of downward entailment across natural languages. The description of downward entailment is the topic of next section.

[15] Downward entailment is the key property to some accounts of the distribution of the word *any* proposed in the literature. Some of these accounts will be reviewed momentarily.

## 1.3 The Property of Downward Entailment

Downward entailment is a semantic property common to various linguistic environments across natural languages. In this section we describe the property of downward entailment, discussing some of the research devoted to this phenomena, and describing the features that are most relevant to the account proposed by Chierchia (2000).

The defining property of downward entailing operators is the licensing of inferences from a set to its subsets. Consider the examples in (15). Adult speakers of English recognize the inferences in (15) as valid. In each example, the difference between the two sentences is that one noun phrase, *paper*, is replaced by another noun phrase, *good paper*, which picks out a subset of the set denoted by the noun phrase *paper*.

(15) a. John has not written a paper yet ⇒ John has not written a good paper yet.
b. Every student who wrote a paper received a grade ⇒ Every student who wrote a good paper received a grade.
c. None of the students wrote a paper yet ⇒ None of the students wrote a good paper yet.
d. None of the students who wrote a paper received a grade yet ⇒ None of the students who wrote a good paper received a grade yet.
e. John fulfilled the requirements of the Syntax seminar without a paper ⇒ John fulfilled the requirements of the Syntax seminar without a good paper.
f. John graduated before he wrote a paper ⇒ John graduated before he wrote a good paper.

As one can observe in (16), it is easy to find linguistic contexts which do not license inferences from a set to its subsets.

(16) a. John has written a paper *⇒ John has written a good paper.[16]
b. Some student who wrote a paper received a grade *⇒ Some student who wrote a good paper received a grade.
c. Some student wrote a paper *⇒ Some student wrote a good paper.
d. One student who wrote a paper received a grade *⇒ One student who wrote a good paper received a grade.

[16] We will use the symbols '*⇒' and '*⇔' to indicate invalid implications and invalid equivalences respectively.

e. John fulfilled the requirements of the Syntax seminar with a paper *⇒ John fulfilled the requirements of the Syntax seminar with a good paper.
f. John graduated after he wrote a paper *⇒ John graduated after he wrote a good paper.

It is important to observe that some minimal pairs of linguistic expressions, which are closely related in meaning, give rise to opposite patterns of inference (i.e., they differ in the direction of the entailment relationship). One clear example is constituted by the preposition *without* versus *with* as shown in (17), and by clauses headed by *before* versus *after* as shown in (18).

(17) a. John fulfilled the requirements of the Syntax seminar without a paper ⇒ John fulfilled the requirements of the Syntax seminar without a good paper.
b. John fulfilled the requirements of the Syntax seminar with a paper *⇒ John fulfilled the requirements of the Syntax seminar with a good paper.

(18) a. John graduated before he wrote a paper ⇒ John graduated before he wrote a good paper.
b. John graduated after he wrote a paper *⇒ John graduated after he wrote a good paper.

A second property of downward entailment concerns the distribution of negative polarity items (NPIs), e.g., the words *any* and *ever* in English (cf. Ladusaw, 1979). As shown in (19) and (20), the environments considered in (15) license such words.

(19) a. John has not written any paper yet.
b. Every student who wrote any paper received a grade.
c. None of the students wrote any paper yet.
d. None of the students who wrote any paper received a grade yet.
e. John fulfilled the requirements of the Syntax seminar without any paper.
f. John graduated before he wrote any paper.

(20) a. John has not ever written a paper.
b. Every student who ever wrote a paper received a grade.
c. None of the students ever wrote a paper.
d. None of the students who ever wrote a paper received a grade.

e. John fulfilled the requirements of the Syntax seminar without ever writing a paper.
f. John graduated before he ever wrote a paper.

The linguistic environments in (16), by contrast, do not license the occurrence of negative polarity items, as shown by the ungrammaticality of the sentences in (21) and (22). As we saw earlier, these same linguistic contexts do not license inferences from sets to subsets.

(21) a. *John has written any paper.
b. *Some student who wrote any paper received a grade.
c. *Some student wrote any paper.
d. *One student who wrote any paper received a grade.
e. *John fulfilled the requirements of the Syntax seminar with any paper.
f. *John graduated after he wrote any paper.

(22) a. *John has ever written a paper.
b. *Some student who ever wrote a paper received a grade.
c. *Some student ever wrote a paper.
d. *One student who ever wrote a paper received a grade.
e. *John fulfilled the requirements of the Syntax seminar with ever writing a paper.
f. *John graduated after he ever wrote a paper.

Again, the distribution of negative polarity items distinguishes between words with related meanings. Consider (23) and (24).

(23) a. John fulfilled the requirements of the Syntax seminar without any paper .
b. *John fulfilled the requirements of the Syntax seminar with any paper.

(24) a. John graduated before he wrote any paper.
b. *John graduated after he wrote any paper.

The third property of downward entailment concerns the interpretation of disjunction. As observed by Boster and Crain (1993), for any downward entailing operator $OP_{DE}$, sentences containing disjunction give rise to entailments of the following sort:

(25) $OP_{DE}(A \text{ or } B) \Rightarrow OP_{DE}(A) \text{ and } OP_{DE}(B)$ [17]

The scheme of inference in (25) closely resembles one direction of entailment of one of the De Morgan's laws for propositional logic.[18]

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[17] It is not entirely clear whether also the inverse direction of the entailment expressed in (25) holds for all DE environments. We refer the reader to Zwarts (1998) for a classification of negative polarity items that is based on the observation that not all DE operators generate entailments according to the scheme in (i).

(i) $OP_{DE}(A) \text{ and } OP_{DE}(B) \Rightarrow OP_{DE}(A \text{ or } B)$

[18] See, for example, Partee, ter Meulen and Wall (1993). The second De Morgan's law is illustrated in (i).

(i) $\neg(P \wedge Q) \Leftrightarrow \neg P \vee \neg Q.$

Although we will not discuss the relevance of this law, it is important to point out that Zwarts (1998) argues that (i) does not hold for *no* and *none of the Ns*, which is the linguistic construction we will investigate. Whether Zwarts' claim about the quantified expression *none of the Ns* is correct is not relevant for the present study. However, it is worth describing briefly some of the examples proposed by Zwarts (1998). Consider the examples in (ii), where the relevant scope is marked by the use of parentheses:

(ii) a. It is not the case that (Jack ate and Jill ran) ⇔ (It is not the case that Jack ate) or (it is not the case that Jill ran).
b. Jack did not (eat and run) ⇔ (Jack did not eat) or (Jack did not run).

The examples in (ii) show that the negative adverb *not* and the sentential prefix *it is not the case that* obey the scheme in (i). According to Zwarts (1998), however, the following sentences show that the quantifiers *no* and *None of the Ns* behave differently.

(iii) a. No man escaped and got killed *⇔ No man escaped or no man got killed.
b. None of the men escaped and got killed *⇔ None of the men escaped or none of the men got killed.

By considering the following examples, however, one can see that the same pattem does emerge for the negative adverb *not* and the sentential prefix *it is not the case that*.

(iv) a. It is not the case that (Jack and John ate or ran) *⇔ (It is not the case that Jack and John ate) or (it is not the case that Jack and John ran).
b. Jack and John did not (eat and run) *⇔ (Jack and John did not eat) or (Jack and John did not run).

Consider (ivb). Suppose that Jack ate but he did not run, while John ran but he did not eat. In such context *Jack and John did not eat and run* is true, while both disjuncts of *Jack and John did not eat or Jack and John did not run* are false. Intuitively, the reason why (ivb) no longer holds, has to do with the interpretation of a plural subject with verb phrases of the form $VP_1$ *and* $VP_2$. For the

(26) $\neg(P \vee Q) \Leftrightarrow \neg P \wedge \neg Q$

It is important to observe that the scheme in (25) proposed by Boster and Crain (1993) extends beyond negation. In particular, (25) holds for any downward entailing operator. Consider the examples in (27).

(27)
a. John has not written a paper or made a presentation yet ⇒ John has not written a paper yet, and John has not made a presentation yet.
b. Every student who wrote a paper or made a presentation received a grade ⇒ Every student who wrote a paper received a grade, and every student who made a presentation received a grade.
c. None of the students wrote a paper or made a presentation yet ⇒ None of the students wrote a paper yet, and none of the students made a presentation yet.
d. None of the students who wrote a paper or made a presentation received a grade yet ⇒ None of the students who wrote a paper received a grade yet, and none of the students who made a presentation received a grade yet.
e. John fulfilled the requirements of the Syntax seminar without a paper or a presentation ⇒ John fulfilled the requirements of the Syntax seminar without a paper, and John fulfilled the requirements of the Syntax seminar without a presentation.
f. John graduated before he wrote a paper or he made a presentation ⇒ John graduated before he wrote a paper, and John graduated before he made a presentation.

As the reader should expect, upward entailing environments do not give rise to inferences of the sort in (25). As a consequence, the inferences in (28) are not recognized as valid by adult speakers of English.

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present purposes, we do not need to provide an explicit account of (iii). Nor do we need to determine whether the examples in (iv) show that the scheme in (i) does not hold for any downward entailing operator. More simply, we believe the examples in (iv) invite us to reconsider Zwarts' claim that sentences like (iii) clearly set aside *no* and *none of the Ns* from sentential negation.

(28) a. John has written a paper or made a presentation *⇒ John has written a paper, and John has made a presentation.
b. Some student who wrote a paper or made a presentation received a grade *⇒ Some student who wrote a paper received a grade, and some student who made a presentation received a grade.
c. Some student wrote a paper or made a presentation *⇒ Some student wrote a paper, and some student made a presentation.
d. One student who wrote a paper or made a presentation received a grade *⇒ One student who wrote a paper received a grade, and one student who made a presentation received a grade.
e. John fulfilled the requirements of the Syntax seminar with a paper or a presentation *⇒ John fulfilled the requirements of the Syntax seminar with a paper, and John fulfilled the requirements of the Syntax seminar with a presentation.
f. John graduated after he wrote a paper or he made a presentation *⇒ John graduated after he wrote a paper, and John graduated after he made a presentation.

It is time to recap. The examples presented above show that sentences containing disjunction in the scope of a downward entailing operator obey a particular inference scheme. Moreover, we have shown that the same scheme of inference does *not* characterize the interpretation of sentences containing disjunction in a *non*-DE environment. Let us now consider the inferences that characterize *non*-DE environments. Across natural languages, many *non*-DE environments seem to obey the scheme of inference reported in (29). This is shown by the examples in (30).

(29) OP(A or B) ⇒ OP (A) or OP(B)[19]

(30) a. John has written a paper or made a presentation ⇒ John has written a paper or John has made a presentation.
b. Some student who wrote a paper or made a presentation received a grade ⇒ Some student who wrote a paper received a grade, and some student who made a presentation received a grade.

[19] Exceptions to the scheme in (29) are easy to come by. As shown in (i), the nuclear scope of the universal quantifier *every* patterns differently.

(i) Every student will write a paper or make a presentation *⇒ Every student will write a paper or every student will make a presentation.

c. Some student wrote a paper or made a presentation ⇒ Some student wrote a paper, or some student made a presentation.
d. One student who wrote a paper or made a presentation received a grade ⇒ One student who wrote a paper received a grade, or one student who made a presentation received a grade.
e. John fulfilled the requirements of the Syntax seminar with a paper or a presentation ⇒ John fulfilled the requirements of the Syntax seminar with a paper, or John fulfilled the requirements of the Syntax seminar with a presentation.
f. John graduated after he wrote a paper or he made a presentation ⇒ John graduated after he wrote a paper, or John graduated after he made a presentation.

Importantly, DE environments do not obey this scheme, and the inferences in (31) are not recognized as valid inferences by adult speakers of English.

(31) a. John has not written a paper or made a presentation yet *⇒ John has not written a paper yet or John has not made a presentation yet.
b. Every student who wrote a paper or made a presentation received a grade *⇒ Every student who wrote a paper received a grade or every student who made a presentation received a grade.
c. None of the students wrote a paper or made a presentation yet *⇒ None of the students wrote a paper yet or none of the students made a presentation yet.
d. None of the students who wrote a paper or made a presentation received a grade yet *⇒ None of the students who wrote a paper received a grade yet or none of the students who made a presentation received a grade yet.
e. John fulfilled the requirements of the Syntax seminar without a paper or a presentation *⇒ John fulfilled the requirements of the Syntax seminar without a paper or John fulfilled the requirements of the Syntax seminar without a presentation.
f. John graduated before writing a paper or making a presentation *⇒ John graduated before writing a paper or John graduated before making a presentation.

It is time to take stock. We have reviewed the main properties of downward entailment. Among these properties, the distribution and the interpretation of *any* have received the greatest attention. Various accounts have been proposed in the literature to provide a unified explanation for these phenomena (e.g., Ladusaw, 1979, Linebarger, 1983; Lahiri, 1997; Kadmon and

Landman, 1993, Dayal, 1998). The proposal adopted by Chierchia (2000) is the one advanced by Kadmon and Landman (1993), which we will describe briefly.

The approach to the distribution and the interpretation of *any* proposed by Kadmon and Landman (1993) consists of three parts. First, *any* is treated as an indefinite, and is therefore expected to display the same kind of variability in its quantificational force revealed by other indefinites. Second, what distinguishes *any* from other indefinites is that *any* widens the domain under consideration. Third, the use of *any* is subject to a semantic constraint, namely *any* "must STRENGTHEN the statement it occurs in, that is the semantic operation associated with it must create a stronger statement."[20] These assumptions allow Kadmon and Landman (1993) to provide an account that is close in spirit to Ladusaw (1979), and which solves some of the problems pointed out by Linebarger (1987).

From an acquisitionist perspective, the property of downward entailment and its consequences across natural languages constitute an interesting domain of research. In particular, one needs to wonder how children make sense of such an intricate pattern of linguistic behavior, exclusively on the basis of positive evidence. This research question will be discussed in more detail in section 2.2. Before turning to child language, however, it is important to describe the role played by downward entailment in Chierchia's account of scalar implicatures.

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[20] Kadmon and Landman (1993; pp. 368-369, emphasis in text). It is important to observe that, in ordinary contexts, a sentence that widens the domain of quantification is less informative than the sentence involving a narrower domain of quantification. Consider the sentences in (i).

(i) a. John wrote a paper.
b. John wrote a good paper.

The sentence in (ia) is clearly less informative than (ib), because it is consistent with a set of possibilities that are excluded by (ib), e.g., the possibility that John wrote a bad paper. The difference in informativeness can be seen also if one considers that (ib) could be the continuation of (ia), but not vice versa.

(ii) a. John wrote a paper, in fact he wrote a good paper.
b. #John wrote a good paper, in fact he wrote a paper.

Notice that the corresponding negative sentences generate the opposite pattern.

(iii) a. #John did not write a paper, in fact he did not write a good paper.
b. John did not write a good paper, in fact he did not write a paper.

## 1.4 The Semantic Core Model of Scalar Implicatures

The Semantic Core model of Scalar Implicatures proposed by Chierchia (2000) attributes a crucial role to entailment relationships. According to this view, scalar implicatures are computed as part of the recursive interpretation of a sentence. Importantly, this amounts to the claim that scalar implicatures must be computed within the semantic component of the grammar. This assumption is therefore incompatible with the modular conception of the semantic/pragmatic interface adopted by the neo-Gricean view as we have described it. In this section we illustrate how the Semantic Core model provides us with an explanation for the puzzle faced by the neo-Gricean view of scalar implicatures.

The Semantic Core model maintains that the computation of scalar implicatures consists of three steps. First, scalar implicatures are introduced for any scalar term in the standard way, (i.e., adding to the interpretation of the sentence an implicature which amounts to the negation of any alternative statement). Second, the result of such computation is compared with the basic interpretation of the target sentence (i.e., the interpretation in which the implicature is not calculated). Third, the interpretation obtained through the computation of the implicature is adopted, only if it leads to a more informative interpretation, i.e., an interpretation that is true in a narrower set of circumstances. Let us illustrate how these steps can account for the interpretation of a sentence like (5), repeated below.

(5) John bought chips or ice cream.

The range of truth conditions that would make such sentence true are the following:

(32) $situation_1$ = John bought chips.
$situation_2$ = John bought ice cream.
$situation_3$ = John bought chips and ice cream.

Now we calculate the implicature, conjoining the sentence under consideration with the negation of the alternative statement containing the scalar term *and*. The result is given in (33), which is true in the range of circumstances in (34).

(33) John bought chips or ice cream, and it is not the case that John bought both chips and ice cream.

(34) $situation_1$ = John bought chips.
$situation_2$ = John bought ice cream.

Since the set of circumstances in which (33) is true is narrower than the set of circumstances in which (5) is true, (33) is adopted for the interpretation of the target sentence.[21] In short, the use of the disjunction operator *or* triggers an implicature of exclusivity, which makes the sentence infelicitous if John bought both chips and ice cream.

Before we consider how the Semantic Core model accounts for the interpretation of scalar terms in downward entailing contexts, it is important to stress one consequence of the account of SIs proposed by Chierchia (2000). The Semantic Core model views the computation of sentences containing scalar terms as resulting from the construction of an alternative representation, which is adopted if more informative than the basic interpretation of the sentence under consideration. Intuitively, the reason behind this constraint is the following: scalar implicatures must make the speaker's assertion more informative. By contrast, if the implicature yields a less informative statement, then the computation of scalar implicatures is unmotivated. It is pertinent to observe that the Semantic Core model accounts for two distinct phenomena. From the speaker's perspective, the notion of information strength determines which scalar term must be used; from the hearer's perspective, the notion of information strength constrain the computation that accounts for the 'derived' interpretation of scalar terms. Let us consider each issue in turn. Using the same scenario we considered above, suppose the speaker knows that John went to the store, and he bought chips and ice cream. Two sentences of English would be true in such context, namely (35) and (36).

(35) John bought chips and ice cream.

(36) John bought chips or ice cream.

Now, although both sentences are true in a context in which John bought both chips and ice cream, the use of (36) is 'banned' by two related factors. First, (36) is less informative because it makes available some of the possibilities that are

[21] Intuitively, the result of the comparison between the basic and the derived interpretation of the target sentence is entirely predictable on the basis of the comparison between the basic interpretation of the target sentence and the relevant alternative statement. For example, consider the sentence *John bought chips or ice-cream.* Since the alternative statement *John bought chips and ice-cream* is true in a narrower set of circumstances, the computation of the implicature (i.e., *it is not the case that John bought chips and ice-cream*) will result in narrower set of circumstances. As a consequence, the constraint on the computation of the implicature could be expressed in two equivalent ways: the implicature arises if its computation leads to a more informative statement, or alternatively the implicature arises if a more informative statement is available. For the present purposes, we can simply view these as notational variant.

excluded by the speaker's conversational background. Second, the speaker knows that upon uttering (36), the hearer will carry out a reasoning similar to the one described above, and adopt the interpretation in (37).

(37) John bought chips or ice cream, and it is not the case that he bought chips and ice cream.

Importantly, such reasoning will lead the hearer to an interpretation that contrasts with the speaker's intended meaning. Therefore, the speaker will use (35).

To recap, information principles influence the interpretation of sentences containing scalar terms in two related ways. First, they invite the speaker to use the most informative sentence (i.e., the sentence that is true in the narrower set of circumstances). Second, whenever the speaker fails to use the most informative sentence, information principles lead the hearer to an interpretation that collides with the speaker's intended interpretation.

Let us resume the description of the Semantic Core model. So far we have described how scalar implicatures influence the interpretation of sentences containing the disjunction operator *or* in *non*-DE contexts. In particular, we have outlined the reasoning which makes sentences of the form *A or B* less informative than *A and B* whenever both *A* and *B* are true.[22] Now consider what happens if the disjunction *or* appears in the scope of a Downward Entailing operator, e.g., the negation *not*. Suppose we hear a sentence like (38).

(38) John did not buy chips or ice cream.

The only set of circumstances that makes such sentence true is the following:

(39) $\text{situation}_1$ = John did not buy chips and John did not buy ice cream.

Now consider what happens when we conjoin this with the alternative statement including the conjunction *and*. We obtain something like (40), which cannot be true in any set of circumstances.

(40) John did not buy chips or ice cream, and it is not the case that John did not buy chips and ice cream.

[22] Strictly speaking, a sentence of the form *A or B* is always less informative than *A and B*. The relative information strength of two sentences, however, only plays a role if the two sentences are both true in the particular situation under investigation. Taking sentences of the form *A or B* and *A and B* as an example, the only situation in which both sentences are true is when both *A* and *B* are true. Therefore, we expect information strength to play a role only in this particular case.

Since the computation of the implicature does not lead to a more informative interpretation than (38), the derived representation in (40) is abandoned.[23] As a consequence, the sentence under consideration is interpreted on its basic interpretation. Crucially, such interpretation makes the sentence true only if John bought neither chips nor ice cream. In short, when *or* occurs in the scope of negation, scalar implicatures do not rule out any of the truth-conditions associated with the inclusive-*or* reading of the disjunction operator *or*.

In the preceding paragraph, we have shown how the Semantic Core model accounts for the accessibility of the full range of truth-conditions associated with inclusive-*or* in downward entailing contexts. This constitutes only one aspect of the computation of scalar implicatures in DE contexts, however. Upon considering DE contexts, in fact, one can observe that scalar implicatures make sentences of the form $OP_{DE}$*(A and B)* less informative than sentences of the form $OP_{DE}$*(A or B)* in contexts that make both sentences true.[24] Consider the example in (41), in which *and* occurs in the scope of negation.

(41) John did not write a paper and make a presentation.

On its basic interpretation, (41) is true in three sets of circumstances:

(42) $situation_1$ = John made a presentation, but he did not write a paper.
$situation_2$ = John wrote a paper, but he did not make a presentation.
$situation_3$ = John neither wrote a paper nor made a presentation.

However, the hearer must compute a derived interpretation, resulting from the conjunction of (41) and the negation of an alternative representation of (41) containing the disjunction *or*.

(43) John did not write a paper and make a presentation, and it is not the case that John did not write a paper or make a presentation.

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[23] This reasoning presents a technical wrinkle. In standard set theory, the empty set is a subset of any set. As a consequence, the interpretation in (40) is more informative than the basic interpretation of (38). Regardless of the particular mechanism we want to invoke to solve this problem, it is important to notice that the notion of information strength is supposed to discriminate between alternative statements that are true. If we allowed false sentences to be considered for the comparison, the notion information strength would yield the undesired consequence of licensing a false interpretation over a true interpretation.

[24] In our discussion, we will assume that the disjunction and the conjunction operators cannot receive wide scope over negation. Although this generalization might not hold for all languages, it seems to describe the scope relations of English (see Guerzoni, 2000; Larson, 1985; Partee and Rooth, 1982).

The situations that verify (43) simply result from the intersection of the situations in which each conjunct is true. We already know that the first conjunct is true in the situations in (42), so let us focus on the second conjunct. A sentence like *It is not the case that John did not write a paper or made a presentation* is true in the following range of circumstances:

(44) $situation_1$ = John made a presentation, but he did not write a paper.
$situation_2$ = John wrote a paper, but he did not make a presentation.
$situation_4$ = John wrote a paper and made a presentation.[25]

Intersecting the range of truth conditions in (42) and (44), the result is that (43) is true in the following range of circumstances.

(45) $situation_1$ = John made a presentation, but he did not write a paper.
$situation_2$ = John wrote a paper, but he did not make a presentation.

As one can easily observe, the circumstances in (45) constitute a subset of the circumstances corresponding to the basic interpretation of (41) (i.e., the sets of circumstances listed in (42)). Therefore, the derived interpretation is a more informative interpretation of the target sentence, and is adopted for the interpretation of *John did not write a paper and make a presentation*. Importantly, the computation of the implicature provides a derived interpretation of (38) which suggests that John either wrote a paper or made a presentation. This result is the reverse of the one that obtains for uses of *or* in *non*-DE contexts. As a consequence of this reasoning, we would expect adult speakers of English to reject (41) in a context in which John did not write a paper and did not make a presentation, on the grounds that a statement like (46) would be more felicitous.

(46) John did not write a paper or made a presentation.

The reasoning we just described can be extended beyond the interpretation of the conjunction *and* in the scope of negation. Any scalar term that yields a more informative statement in a *non*-DE environment, as compared to an alternative term on the same scale, will yield a less informative statement in the scope of a downward entailing operator. Observing this property of scalar terms, Chierchia (2000) claims that DE contexts reverse the information scale.

The reversion of the scale follows under any account that ties the notion of information strength to entailment relationship. Consider the scalar terms *and* and *or*. As we have repeatedly observed, the sets of circumstances that verify

[25] We are still assuming that the semantic component of the grammar assigns an inclusive-*or* interpretation to the disjunction operator.

sentences of the form *S(A and B)* is a subset of the circumstances that verify *S(A or B)*. As a consequence, a cooperative speaker should use *S(A and B)* when both *S(A)* and *S(B)* are true. Now consider two sentences of the form *it is not the case that (A and B)* and *it is not the case that (A or B)*. The sentence *it is not the case that (A or B)* is true in a subset of the circumstances in which *it is not the case that (A and B)* is true. As a consequence, when both sentences are true (i.e., *A* is false and *B* is false), a statement of the form *it is not the case that (A or B)* is more informative. More generally, given two sentences $S_1$ and $S_2$ involving a *non*-DE operator such that $S_1$ is stronger than $S_2$ and $S_1$ and $S_2$ only differ in the use of a scalar term, $OP_{DE}S_2$ is stronger than $OP_{DE}S_1$ in the specific context that makes both $OP_{DE}S_2$ and $OP_{DE}S_1$ true. In section 3.3 we present the results of two experiments investigating the extent to which adults' interpretation of scalar terms conforms to the reversion of the scale.

It is important to be explicit about the role of information principles in the Semantic Core model. We have argued that the Semantic Core model maintains that the speaker should use the most informative statement consistent with his knowledge, and the hearer's interpretation is guided by the assumption that the speaker is being cooperative. These assumptions alone do not distinguish the Semantic Core model from the neo-Gricean view. The Semantic Core model, however, presents two important differences. First, the Semantic Core model can explain the cancellation of scalar implicatures in downward entailing contexts. Second, the Semantic Core model brings a new issue to our attention, namely the domain in which the computation of scalar implicatures takes place. Let us consider each issue in turn.

As we have seen in the paragraphs above, the Semantic Core model maintains that the computation of scalar implicatures is subject to one constraint: the computation of the implicatures associated with a scalar term must lead to a more informative statement. For example, the implicature for a sentence *S* containing the disjunction operator *or* (i.e., *not S(and)*) cannot be added to the basic interpretation if the result of the computation (i.e., *S(or) and not S(and)*) is less informative than *S(or)*. This explains why the implicature is added for (47a), but not for (47b).

(47) a. John bought chips or ice cream.
b. John didn't buy chips or ice cream.

Moreover, the fact that entailment relationships are reversed in a variety of linguistic contexts extends the relevance of the Semantic Core model beyond sentential negation. This constitutes an important difference between the Semantic Core model and the standard neo-Gricean view, as the neo-Gricean view does not attribute any role to the specific linguistic contexts in which scalar terms occur. In

other words, the neo-Gricean view concedes that scalar implicatures fail to arise in particular conversational contexts. The neo-Gricean view, however, cannot explain why scalar implicatures arise or fail to arise for sentences that are uttered in the same conversational context, but differ in their *linguistic* properties, like the sentences in (48).

(48) a. John graduated before he wrote a paper or made a presentation.
b. John graduated after he wrote a paper or made a presentation.

The second innovative aspect of the Semantic Core model lies in the fact that it raises a new research question, namely in what domains the computation of SIs takes place. It is important to keep in mind that the licensing conditions of the NPI *any* must be satisfied locally. Consider for example the contrast in (49), adapted from Chierchia (2000).

(49) a. I doubt that Sue has any potato.
b. *I doubt that every student has any potato.

The verb *doubt*, which creates a downward entailing environment, licenses the occurrence of *any* in (49a), but not in (49b). Given the pattern in (49) and the correlation between scalar implicatures and entailment relationships, a question immediately arises: is the computation of scalar implicatures subject to the same locality conditions as the licensing of NPIs? Answering this question is beyond the scope of the present study.[26] In our view, however, this question can only be motivated if we allow principles that are traditionally thought to be part of the pragmatic module to operate within the semantic component of the grammar, since under the neo-Gricean view no pragmatic principle is assumed to make reference to sub-sentential domains.

A final remark about modularity is in place. We have observed that the neo-Gricean view of scalar implicatures was consistent with a modular conception of the grammar, according to which pragmatic principles discriminate between alternatives licensed by the semantic component. In light of the examples discussed above, the assumption that all pragmatic principles operate after the semantic component of the grammar has specified an interpretation is no longer tenable. In particular, we have repeatedly observed that the Semantic Core model

[26] The idea that scalar implicatures apply after the principles of semantics assign an interpretation to the sentence is incompatible with the idea of a constraint defined in terms of entailment relationship. It is important to stress that if one adopts recent theories which identify directional entailment on the basis of natural language syntax, one needs to conclude that the computation of scalar implicatures takes place even before principles of semantics could apply (for a syntactic account of directional entailment see Ludlow, forthcoming).

maintains that the computation of scalar implicatures may be preempted because of some linguistic properties. A consequence of this assumption is that scalar implicatures are not computed if a scalar term occurs in a downward entailing environment, regardless of the conversational context (description vs. conditions of uncertainty). This does not mean, however, that the conversational context does not play any role under different circumstances. In more precise terms, the Semantic Core model limits the role of the conversational context to the cases in which the computation of scalar implicatures does indeed lead to a more informative statement. Whenever this is the case, the implicature is licensed by the constraint on informativeness, but the particular conversational context in which the utterance takes place gets to determine whether it should be defeated.

To recap, under the Semantic Core model, the computation of scalar implicatures is subject to a constraint: SIs must lead to a stronger statement. Moreover, since the notion of information strength draws upon entailment relationships, the result of the computation of SIs depends on the specific linguistic environment in which a scalar term occurs. By making reference to a linguistic domain that is smaller than the matrix sentence (e.g., the restrictor or the nuclear scope of a quantifier), one can no longer assume that the computation of scalar implicatures takes place after the grammar has completed its job. In section 3.3, we describe the results of some recent experiments designed to investigate if children's and adults' computation of SIs conforms to the predictions of the Semantic Core model.

## 2 Children's Knowledge of Scalar Implicatures and Downward Entailment

### 2.1 Children's Interpretation of Scalar Terms

The neo-Gricean view of scalar implicatures contributed to important insights into children's interpretation of sentences containing logical words. In recent years, linguistically motivated studies have shed a new light on the conflicting findings from previous research. Previous research on children's interpretation of sentences containing logical words led to the claim that children's interpretation of such words does not conform to standard logic.[27] More recent studies, however, have reached exactly the opposite conclusion. In particular, drawing upon the assumptions of the neo-Gricean view, some researchers have argued that in order to assess children's interpretation of logical words, one needs to control for the

[27] With particular reference to disjunction, experimental findings have led to the claim that the full range of truth-conditions associated with inclusive-*or* is initially unavailable to children; instead, children are supposed to interpret disjunction using the truth conditions associated with exclusive-*or* (e.g., Beilin and Lust, 1975; Braine and Rumain, 1981, 1983; Paris, 1973).

factors that influence the *use* of such words in ordinary contexts. In this section we review the findings of this more recent line of research.

As we have observed in section 1.1, scalar implicatures are not computed whenever the hearer knows that the speaker has incomplete knowledge (e.g., in situations of uncertainty). The observation that scalar implicatures are cancelled in contexts of uncertainty has led Chierchia, Crain, Guasti and Thornton (1998) to conduct a series of experiments investigating children's interpretations of logical words in various conversational contexts. In order to assess children's interpretation of logical words when scalar implicatures are cancelled, Chierchia et al. (1998) designed a variant of the Truth Value Judgment task. Before we describe the results of the Chierchia et al. study, it is important to review the fundamentals of design of the Truth Value Judgment task.

The Truth Value Judgment is an experimental technique that allows one to investigate whether a specific interpretation of a target sentence is licensed by the child's grammar (Crain and McKee, 1985; Crain and Thornton, 1998). In a Truth Value Judgment task, one experimenter acts out a short story in front of the child, using props and toys. The story constitutes the context against which the target sentence, uttered by the puppet manipulated by a second experimenter, is evaluated. The acceptance of the target sentence is interpreted as indicating that the target sentence can receive an interpretation that is true in the context under consideration. By contrast, the rejection of the target sentence is interpreted as suggesting that the child's grammar does not license any interpretation that makes the target sentence true in the context under consideration.[28] In order to test children's interpretation of sentences containing the disjunction operator *or* and the quantifier *some*, Chierchia et al. (1998) modified the experimental design so that the storyteller would stop before the end of the story, and ask the puppet to express a prediction about what would happen in the remainder of the story. This variant of the Truth Value Judgment task was called the Prediction Mode. Adopting the Prediction Mode, Chierchia et al. (1998) were able to show that children ignore scalar implicatures in contexts of uncertainty, thereby accessing the full range of truth conditions associated with disjunction (i.e., the inclusive-*or* interpretation) and with the determiner *some* (i.e., the *some and possibly all* interpretation).

The possible methodological problems associated with the Prediction Mode have been addressed by Gualmini, Crain and Meroni (2000). Since the experimental hypothesis was associated with the affirmative response, the same

[28] The Truth Value Judgment task, like any other form of investigation, cannot be used to conclude that a specific interpretation for the target sentence is not available to the child under any circumstance. Although such conclusion cannot be proven, it can receive considerable support if the experimenter respects all the features of design and performs a series of manipulations of the context (see Crain and Thornton, 1998).

response children give when they are confused, the results obtained by Chierchia et al. (1998) could depend on the child's failure to remember the target sentence. To address this potential problem, Gualmini et al. (2000) tried to minimize the processing cost of the Prediction Mode of the Truth Value Judgment task, which requires the child to hold the target sentence in memory until the story is completed. The experiment designed by Gualmini et al. (2000) took the form of a game in which the puppet had to guess what toys would be hidden behind the curtains of a small theater. In making its guessing, the puppet used a conditional statement like (50).

(50) If a gorilla or a zebra appears on the stage, then I get a coin.

Immediately after the puppet's statement, the contents of the stage were revealed, and the child was asked whether the puppet should receive a coin. It is important to notice that when the puppet makes its guess, there is uncertainty as to which particular toy will subsequently appear on the stage. This condition of uncertainty makes the inclusive-*or* reading of disjunction felicitous. The memory load associated with the task, however, is lower than the one involved in the Prediction Mode, since a very short time separates the puppet's assertion and the time in which the child can evaluate such assertion. Adopting this variant of the Truth Value Judgment task, Gualmini et al. (2000) showed that three and four-year-old children consistently accessed the inclusive-*or* reading of the disjunction operator in the antecedent of conditional sentences.

The same experimental setting was adopted by Broman Olsen and Crain (2000). These authors reported the results of an experiment designed to investigate children's interpretation of the indefinite article *a* in the antecedent of conditional sentences. Consistently with the results of the study by Gualmini et al. (2000), the children who participated in the study by Broman Olsen and Crain (2000) accepted the *at least one* reading of the indefinite article when *a* appeared in the antecedent of conditionals (e.g., *If a strawberry appears on the stage, then I get a coin*).

Taken together, these experimental results show that children can access the full range of truth-conditions associated with logical words, when scalar implicatures are cancelled. Let us now consider the second research question addressed by previous studies on children's interpretation of scalar terms, namely whether children compute SIs whenever the speaker can be assumed to have knowledge about the situation he is describing. In order to address this question, Broman Olsen and Crain (2000) tested children's interpretation of the indefinite article *a* in the consequent of conditional sentences. Children were introduced to two puppets. One puppet was a magician, Merlin, who could make things appear by saying some magic words. The second puppet was Kermit the Frog, who

wanted to become a magician, and was trying to figure out what happens after Merlin has said certain magic words. In a typical trial, Merlin pronounced the magic word "abracadabra." Afterwards, three strawberries had appeared. Then, Kermit produced the target sentence (51).

(51) If Merlin says "abracadabra," a strawberry appears.

The results showed that only older kids would reject test sentences like (51), and point out that (52) would have been a better description of Merlin's magic trick.[29]

(52) If Merlin says "abracadabra," three strawberries appear.

As a follow-up study, Broman Olsen and Crain (2000) conducted an Act-Out task similar to the one conducted by Braine and Rumain (1981). Children were asked to "give an *X*" to the experimenter, in a situation in which several *Xs* were available in the experimental workspace. In this condition, even younger children picked a single *X*, thereby showing a strong preference for the *exactly one* reading of the indefinite article. Overall, the interpretation of the findings provided by Broman Olsen and Crain (2000) is that children have implicit knowledge of scalar implicatures, but this knowledge fails to govern children's behavior in the same way it governs adults' behavior.

A similar conclusion has been reached by Noveck (2001), who investigated children's interpretation of the French determiner *certain*, which corresponds to the English determiner *some*. Noveck (2001) tested children's computation of the scalar implicature associated with *certain* by asking them to evaluate sentences like (53).

(53) Some giraffes have long necks.

The results show that even 10-year-old children would rarely reject the target sentence (i.e., 15% of the time), whereas adult controls rejected the target sentence 59% of the time, on the grounds that a statement like (54) was more felicitous.

(54) All giraffes have long necks.

The interpretation of the findings proposed by Noveck (2001; p. 183) is that "Gricean implicatures are present in adult inference making but that in cognitive development they occur only after logical interpretations are well established."

[29] The results obtained by Broman Olsen and Crain (2000) show a correlation between age and computation of scalar implicatures centering around 5 years of age.

Commenting on children's knowledge of scalar implicatures, Noveck writes: "the paper is only claiming that the competent use of a weak scalable term is linked initially to an explicit interpretation and that this is *followed by* a pragmatic one. This is drawn out by the results. By no means do I want to suggest that children are incapable of pragmatic inferencing at younger ages."[30] This qualification, however, is not followed by any description of the pragmatic inferences that younger children are able to perform.

To sum up, the results we have reviewed invite two conclusions about children's interpretation of scalar terms. First, experiments investigating children's interpretation of scalar terms in contexts of uncertainty demonstrate their ability to access the full range of truth conditions associated with scalar terms, e.g., the inclusive-*or* reading of disjunction, the *at least one* reading of the indefinite article *a*, and the *some and possibly all* interpretation of the determiner *some*. Second, experiments using the Description Mode of the Truth Value Judgment task have failed to show children's explicit knowledge of scalar implicatures, but there is some experimental evidence of children's computation of scalar implicatures. The confirmation of children's knowledge of scalar implicatures, however, comes largely from experiments adopting the Act-Out task, a research technique that presents some limitations when applied to linguistic research (see Crain and Thornton, 1998).[31] In section 2.3, we will observe that the same conclusion is invited by the recent findings of experiments inspired by the Semantic Core model proposed by Chierchia (2000). Before we describe these experiments, however, it is important to review previous research on children's knowledge of downward entailment, a semantic property which figures centrally in Chierchia's account.

## 2.2 Children's Knowledge of Downward Entailment

As we have seen in section 1.3, downward entailing operators display a complex set of distributional and semantic properties. Consider the distribution of negative polarity items (NPIs). The occurrence of negative polarity items in adult languages is restricted to particular linguistic environments, namely downward entailing contexts. Importantly, we have observed the existence of pairs of

[30] Noveck, (2001; p. 184, italics in text).

[31] The main problem of the Act-Out task is that it cannot be used to investigate exhaustively a range of alternative interpretations for a particular linguistic construction. On the basis of the results of an Act-Out task, one can infer that a particular interpretation is licensed by the subject's grammar. The findings of an Act-Out task, however, cannot be used to infer that the subject's grammar does not license any other interpretation. We refer the reader to the detailed criticism of the Act-Out task presented by Crain and Thornton (1998).

expressions which differ in the licensing of NPIs, in spite of their related meaning. From an acquisitionist perspective, two related questions immediately arise: is child language qualitatively different from the adult language? Is there a stage in the course of language development, during which children use NPIs differently from adults? Consider now the logical properties of downward entailment. We have seen that the interpretation of sentences containing the disjunction *or* is sensitive to the entailment properties of the linguistic environment it occurs in. Again, is there a stage in the course of language development, during which children interpret sentences containing disjunction *or* in a DE linguistic environment differently from adults? Some of these questions have been addressed by previous studies, and a summary of the main findings is reported below. Before reviewing previous research on children's knowledge of downward entailment, it is important to reflect on how the child could attain such knowledge.

Let us consider how a child could come to master all the properties related to the direction of entailment relationships. As we have repeatedly observed, downward entailment characterizes various operators across natural languages. Intuitively, some of the properties that are related to downward entailment seem easier to detect. For example, the distribution of negative polarity items is more easily observable than the direction of entailment relations. At first sight, the correlation between the distribution of negative polarity items and entailment properties constitutes an important factor from the language learner's perspective. In particular, the language learner could use the distribution of negative polarity items to classify linguistic contexts in two classes. In other words, one could argue that the child learns what contexts are downward entailing on the basis of the distributional evidence available to her, namely the distribution of NPIs. Under this view, the child's biological endowment would lead her to scan the input for distributional regularities. On this conservative model of language learning, at any given moment of language development the hypothesis that the child entertains would be constrained by the kind of evidence encountered by the language learner. Appealing as it may be, this view ignores two important aspects of entailment properties: namely the fact that DE contexts also share other linguistic properties, and the relationship between the meaning of an expression and the kinds of entailments this expression generates. Let us consider each aspect in turn.

The distinction between downward entailing and *non*-DE environment is part of the linguistic knowledge that the child eventually acquires. What the child has to learn, however, is not merely a classification between two contexts. The child acquires the distinction between DE and *non*-DE environments and the whole range of properties that correlate with this distinction. In other words, the distribution of negative polarity items could lead the child to the correct

classification between DE and *non*-DE contexts. From the child's perspective, however, the relevance of this classification between DE and *non*-DE would not extend beyond the distribution of negative polarity item. As a consequence, if children approached the acquisition of downward entailment in this conservative fashion, we would expect that at some point of language development they would behave like adults with respect to one property of DE (i.e., the licensing of negative polarity items), but not with respect to some other property of downward entailment (e.g., the generation of entailments in accordance with the De Morgan's law)

Let us now consider the relationship between the meaning of a linguistic expression and the entailment relationships such expression generates. The property of downward entailment is closely related to the meaning of some linguistic environments across natural languages. It is therefore misleading to ask how a child might learn that, for example, both the restrictor and the nuclear scope of the determiner *no* are downward entailing without considering how the child might learn the meaning of the determiner *no*. In other words, the entailment relationships displayed by the determiner *no* are not an accidental property of the determiner *no*. The entailment relationships displayed by the determiner *no* directly follow from the meaning of the determiner *no*, and the meaning of a determiner cannot be acquired on the basis of distributional evidence.[32] In particular, we believe the acquisition of determiner meanings is heavily constrained by the Universal Grammar, such that only a finite set of the possibly

[32] The relation between the meaning of a determiner and the direction of the entailment relationship of its nuclear scope becomes very intuitive if we just conceive the meaning of a determiner as a relationship between the sets denoted by its restrictor and nuclear scope. Consider a sentence like (i).

(i) No person can fly.

Intuitively, the sentence in (i) is true because the set of men and the set of entities that can fly are disjoint, i.e., they generate an empty intersection. Now, consider the sentences in (ii), in which the we restrict the denotation of the noun phrase *person* and of the verb phrase *can fly* to a subset of their denotation in (i).

(ii) a. No young person can fly.
b. No person can fly above the clouds.

Clearly, the sentences in (ii) are true. This should not be surprising, however. If the intersection between the set of men and the set of things that can fly is empty, reducing the 'size' of either set will not produce any change. A change could only derive if we increased the set picked up by the restrictor or by the nuclear scope.

infinite hypotheses about determiners meaning are entertained by the child.[33] Under this hypothesis, we therefore expect children's knowledge of downward entailment to be essentially adult-like from the earliest stages of language development. In particular, we expect children to be like adults in the classification of a linguistic context as downward entailing or *non*-DE, since natural languages do not differ in this respect. Children might differ from adults, however with respect to the items classified as negative polarity items, something which differs across natural languages. Let us consider if these predictions can be confirmed on the basis of results of previous studies.

Research on children's knowledge of Downward Entailment focused on the licensing conditions and the interpretation of the negative polarity item *any*.[34] Children's knowledge of the licensing conditions of the negative polarity item *any* has been investigated by O'Leary and Crain (1996). These researchers conducted an Elicited Production task with 11 children (ages: 4;4 to 5;4) evoking downward entailing and *non*-DE linguistic environments in the child's response.[35] In order to evoke a DE context, one experimenter acted out a short story about some dogs. Some of these dogs were very hungry, and eventually found some food. However, one dog decided not to eat any food. At this point, the puppet manipulated by a second experimenter uttered the target sentence in (55), which children consistently rejected.

(55) Every dog got some food.

The interesting result of the experiment lies in the responses that children gave when asked "what really happened in the story." In accordance with the licensing conditions of *any* in the adult grammar, children often used the NPI *any* in the scope of negation in their response, uttering sentences like (56).

(56) No, this dog did not get any food!

In the experimental condition designed to evoke *non*-DE contexts, children were presented with a story in which every dog did in the end get some food. In this context, children rejected the target sentence uttered by the puppet (i.e., for example (57)), and described what really happened in the story by using sentences

[33] For example, Meroni, Gualmini and Crain (2000) argued that linguistic universals, such as the assumption that determiner meanings are conservative, restrict the hypotheses a child might entertain.

[34] We refer the reader to Musolino, Crain and Thornton (2000) for a detailed review of previous research on downward entailment and negative polarity items in child language.

[35] The Elicited Production task is described in great detail by Thornton (1996) and Crain and Thornton (1998).

like (58a). Importantly, sentences like (58a), in which the NPI *any* lacks a proper licensor, are almost unattested in children's responses.

(57) Only one dog got any food.

(58) a. No, every dog got some food!
b. *No, every dog got any food!

In other words, despite the experimenter's use of the negative polarity item *any*, children refrained from using *any* in upward entailing contexts, such as the nuclear scope of the universal quantifier *every*.[36]

Another study of negative polarity phenomena in child language has been conducted by van der Wal (1996), who used an Imitation task, as well as a Grammaticality Judgment task. Consistently with the results obtained by O'Leary and Crain (1994), the findings reported by van der Wal (1996) show that Dutch-speaking children obey the restrictions on negative polarity items of the target grammar, from the earliest stages of language development.

The interpretation of the negative polarity item *any* in the scope of negation was investigated in a study by Thornton (1995). Using a Truth Value Judgment task, Thornton (1995) investigated whether children are aware of the differences in meaning between the questions in (59) and (60).

(59) Didn't any of the turtles buy an apple?

(60) Did any of the turtles not buy an apple?

It is important to notice that in (59), *any* is interpreted as an existential quantifier within the scope of negation. In (60), by contrast, the negative polarity item *any* is interpreted as an existential quantifier which takes scope over negation. The responses collected by Thornton (1995) show that children as young as 3;6 discriminate between these two interpretations. In particular, children responded "yes" to questions like (59) if there was at least one turtle that had bought an apple, and they responded "yes" to questions like (60) if there was at least one turtle that had *not* bought any apple.

[36] It is worth observing that children's use of positive polarity items is not fully adult-like. In particular, O'Leary and Crain (1994) reports cases in which children produced the positive polarity item *some* in the scope of negation. A possible interpretation of these findings is that English-speaking children may incorrectly classify *some* as a negative polarity item. The same conclusion is invited by a series of experimental investigations conducted by Musolino (1998a, b) showing that children allow a non adult-like interpretation of *some* in the scope of negation.

The logical properties of *non*-DE operators have been investigated by Boster and Crain (1993). These researchers investigated children's interpretation of sentences containing disjunction in the nuclear scope of the universal quantifier *every*. The research question addressed in the Boster and Crain study was whether children would extend the application of the De Morgan's law to *non*-DE environments. In order to address this question, Boster and Crain (1993) designed a Truth Value Judgment task employing the Prediction Mode. Children were asked to evaluate sentences like (61), in various scenarios.

(61) Every ghostbuster will choose a cat or a pig.

The results obtained by Boster and Crain (1993) provide evidence that children do not treat the nuclear scope of the universal quantifier *every* as downward entailing, i.e., children did not interpret (61) as equivalent to (62).

(62) Every ghostbuster will choose a cat and every ghostbuster will choose a pig.

The experimental findings show that children do not extend the pattern of inference that characterizes downward entailing environments to *non*-DE environments.[37] It is pertinent to observe that the study by Boster and Crain (1993) does not address a related question, namely whether children extend the inference scheme of *non*-DE contexts to downward entailing contexts. In section 3.2, we present an experiment designed to answer this question.

## 2.3 Children's Computation of Scalar Implicatures in Downward Entailing and *non*-Downward Entailing Contexts.

The research on children's computation of scalar implicatures that we summarized in section 2.1 was motivated by the neo-Gricean view of scalar implicatures. All the experiments we described drew upon the distinction between contexts in which scalar implicatures arise, or fail to arise, because of the amount of information available to the speaker. An additional set of research questions

[37] Boster and Crain (1993) discovered some non-adult behavior in children's interpretation of the sentences under investigation. In particular, children generally accepted (61) in a context in which every ghostbuster had chosen exactly one object. However, almost every child imposed an additional restriction on the interpretation of (61). One group of children expected the kind of animal chosen by the ghostbuster to be the same for all ghostbusters, and a second group of children expected the kind of animal chosen by the ghostbuster *not* to be the same for all ghostbusters. We refer the reader to the original paper for a discussion of the experimental results.

arises, however, in light of Chierchia's (2000) account of scalar implicatures. In a series of experiments motivated by the Semantic Core model, Chierchia et al. (2001) investigated children's and adults' computation of scalar implicatures in the restrictor and in the nuclear scope of the universal quantifier *every*.

The restrictor and the nuclear scope of the universal quantifier *every* differ in that only the restrictor is a downward entailing environment. As shown by (63a), the restrictor of the universal quantifier *every* licenses the negative polarity item *any*. By contrast, the nuclear scope of the universal quantifier *every* is not downward entailing, as shown by the ungrammaticality of (63b).

(63) a. Every student who wrote any paper received a good grade.
b. *Every student wrote <u>any</u> paper.

As we have seen in section 1.4, the Semantic Core model maintains that scalar implicatures are not computed in DE environments, as in these environments the computation of Scalar Implicatures would lead to a less informative statement. Accordingly, the Semantic Core model predicts that the implicature of exclusivity for disjunction will arise for sentences like (64b), but not for sentences like (64a).

(64) a. Every student who wrote a paper or made a presentation received a good grade.
b. Every student wrote a paper or made a presentation.

Adults' intuition about the sentences in (64) seems to conform to the prediction of the Semantic Core model. First, consider (64a). Adult speakers of English agree that if every students wrote a paper and made a presentation, they should all receive a good grade. Second, adult speakers of English agree that (64b) is infelicitous in a context in which every student wrote a paper and made a presentation. To evaluate if children's interpretation of sentences like (64) also conforms to the predictions of the Semantic Core model, Chierchia et al. (2001) conducted two experiments, employing the Description Mode of the Truth Value Judgment task.

The first experiment conducted by Chierchia et al. (2001) tested children's acceptance of the inclusive-*or* reading of disjunction in the restrictor of the universal quantifier *every*. In one of the trials, children were told a story about four dwarves at a picnic who were promised a jewel in case they chose healthy food. Three of the dwarves wanted to receive a jewel, so they chose fruit (a banana and a strawberry) and received a jewel from Snow White. By contrast one of the dwarves chose potato chips, and did not receive any jewel from Snow White. At the end of this story, a puppet produced the following target sentence.

(65) Every dwarf who chose a banana or a strawberry received a jewel.

It is important to observe that the target sentence is true only if the disjunction operator *or* is interpreted under the inclusive-*or* reading. Therefore, if children (and adults) compute scalar implicatures and interpret the target sentence under the (derived) exclusive-*or* reading of disjunction, they should reject the puppet's assertion. Fifteen children (age from 3;7 to 6;3; mean age: 4;11) correctly accepted the target sentence 55 times out of 60 trials (91.6%). A group of 11 English-speaking adults correctly accepted the target sentence 42 times out of 44 trials (95.5%). The second experiment conducted by Chierchia et al. (2001) tested children's acceptance of the inclusive-*or* reading of disjunction in the nuclear scope of the universal quantifier *every*, a *non*-DE context. Children were told a story about four boys at the summer camp who are choosing some toys to play with. After considering their options, the four boys took both a skate-board and a bike. At this point, a puppet produced the following target sentence.

(66) Every boy chose a skate-board or a bike.

Importantly, if *or* is interpreted as inclusive-*or* then the target sentence is true but infelicitous. Fifteen different children (age from 3;5 to 6;2 mean age: 5;2) participated in this experiment. Each child was presented with four target sentences. Children accepted the target sentence only 30 times out of 60 (50%).[38] Eight English-speaking adults were tested as control group, and they never accepted the target sentence.

The experimental responses given by the adult controls are perfectly consistent with the Semantic Core model, and show that the implicature of exclusivity is cancelled in the restrictor of the universal quantifier *every* (a downward entailing environment), but not in the nuclear scope of the universal quantifier *every* (a *non*-DE environment). As for children's responses, only one group of subjects behaved as predicted by the Semantic Core model. Thus, the natural question is: why did some children accept sentences containing *or* in the nuclear scope of the universal quantifier *every* in a context in which *and* would be more appropriate? In order to address this question, it is important to decompose the task that children were asked to perform in the judgment of a sentence like (67).

[38] An important feature of the results obtained by Chierchia et al. (2001) lies in the fact that children could be divided in two distinct groups: one group of children consistently applied scalar implicatures, and a second group consistently ignored scalar implicatures. We refer the reader to the original study for a discussion of the individual results, and to Thornton and Wexler (1999) for the implications of this kind of distribution of experimental results.

(67) Every boy chose a skate-board or a bike.

Intuitively, children's task in the experiment conducted by Chierchia et al. (2001) was not simply to evaluate (67) on its basic interpretation. Since the target sentence contains a scalar term, the task involves at least the following steps. First, the child hears the target sentence. Second, the child must acknowledge that an alternative sentence was available as a description of the context under consideration, namely (68), although such sentence was not used by the puppet.

(68) Every boy chose a skate-board and a bike.

Third, the child constructs a derived interpretation of the target sentence, resulting from the conjunction of (67) and the negation of (68).

(69) Every boy chose a skate-board or a bike, and it is not the case that every boy chose a skate-board and a bike.

At this point, the child must compare (67) and (69) in order to determine if the implicature leads to a more informative statement. Since (69) is indeed more informative than (67), the child should adopt the former as the interpretation of (67), and therefore reject the target sentence. Importantly, this reasoning rests on the assumption that the child will not base his judgment on the truth of the target sentence in the context under consideration, but will respond to the informativeness of the target sentence.

It is pertinent to observe that, according to this description, children and adults are not expected to evaluate the target sentence (on either interpretation) until all the steps associated with the computation of the implicature have been carried out. Let us focus on one of these steps, namely the comparison between the basic and the derived interpretation of the target sentence. Can we expect four-year-old children to perform this step? A recent proposal by Reinhart (1999) argues that this kind of computation exceeds children's processing capacities. Here is how Reinhart (1999) illustrates this hypothesis taking children's failure to obey the restrictions on pronouns interpretation as an example: "Assuming that all linguistic knowledge is innate, children know that they have to construct a reference set, keep two representations in working memory, and check whether the interpretation needed in the given context justifies selection of coreference. So they start execution. But their working memory is not big enough to hold the materials needed to complete the execution of this task. Hence they give up and resort to a guess."[39] Although it is not entirely clear whether children resort to a

[39] Reinhart (1999; p. 16).

guess pattern or a default form, the Reference Set hypothesis put forth by Reinhart (1999) seems to cover a wide set of linguistic phenomena which cause problems to young children: focus constructions, anaphora resolution, and double object constructions. As proposed by Chierchia et al. (2001), the same mechanism might be at the source of children's non-adult interpretation of scalar terms, since according to Chierchia's model the computation of scalar implicatures involves a local comparison.

The Processing Limitation hypothesis proposed by Chierchia et al. (2001) is a variant of the Reference Set hypothesis. In particular, the Processing Limitation hypothesis maintains that pragmatic knowledge is available to children, but the computation prompted by such knowledge cannot be completed under particular circumstances. On this view, children know that the interpretation of a sentence containing a scalar term involves the computation of an implicature. The local comparison involved by the computation of the implicature, however, exceeds their limited processing capacities. It is important to stress that on the Processing Limitation hypothesis, children are expected to behave like adults in any task that does not require the construction of an alternative representation, and the comparison between this alternative representation and the target sentence. In other words, children are expected to behave like adults in any task assessing the pragmatic knowledge on which the computation of scalar implicatures hinges. For example, the Processing Limitation hypothesis maintains that children should behave like adults in any task which directly tested their knowledge of information strength. In order to evaluate this hypothesis, Chierchia et al. (2001) devised a new experimental technique, called Felicity Judgment task.

The Felicity Judgment task involves the presentation of pairs of assertions to the subject. In one of the trials, children were told a story about some farmers cleaning their animals. After looking at all the animals, each farmer decided to clean a horse and a rabbit. At this point, the two puppets provided their description of the story (e.g., (70) and (71)), and the child is asked to reward the puppet "who said it better."

(70) Every farmer cleaned a horse or a rabbit.

(71) Every farmer cleaned a horse and a rabbit.

The fifteen children (age from 3;2 to 6;0 mean age 4;7) who participated in this experiment correctly rewarded only the puppet who had used the conjunction *and* in 56 cases out of 60 trials (93.3%). This result clearly shows that children know that (70) and (71) differ in information strength.

The explanation offered by Chierchia et al. (2001) for this set of findings is that children have knowledge of scalar implicatures, and know that sentences of

the form *A and B* are more informative than sentences of the form *A or B*. To explain the non-adult behavior of some children in the second experiment adopting the Truth Value Judgment task, Chierchia et al. (2001) adopt a variant of the Reference Set hypothesis proposed by Reinhart (1999), which we reviewed in the paragraphs above. According to such hypothesis, children's working memory limitations affect the processing of sentences whose interpretation involves the comparison of a set of alternative representations. This does not mean that children are unable to perform any kind of comparison based on information strength. In particular, the results of the Felicity Judgment task show that children can carry out the comparison between two alternative sentences that are readily available to them. Therefore, the source of children's difficulty could be in the construction of the relevant alternative representation and in the withholding of this alternative representation in memory.

It is important to be explicit about what conclusion is supported by the experimental findings reported by Chierchia et al (2001). In our view, children's behavior in the experiment using the Felicity Judgment task shows that children make use of the notion of information strength. In short, the results provided by Chierchia et al. (2001) show that children must be granted some pragmatic knowledge. Assuming that children can distinguish between two sentences on the basis of their information strength, it remains unclear why some children did not rely on information strength when presented with a single assertion. The explanation proposed by Chierchia et al. (2001) is that the computation of scalar implicatures involves a comparison between the basic and the derived interpretation of the target sentence, and that children cannot maintain in memory the two interpretations of the target sentence to carry out this comparison. On this account, the results of the Felicity Judgment task show that children can make use of the notion of information strength to discriminate between alternative sentences, a prerequisite for the computation of scalar implicatures.

The results of the Felicity Judgment task, however, cannot be interpreted as showing that presenting the child with both alternative representations facilitates the computation of the implicature. In particular, the Felicity Judgment task involves the presentation of two possible descriptions of the scenario under consideration (i.e., *Every farmer cleaned a horse or a rabbit* and *Every farmer cleaned a horse and a rabbit*, in the example above). The Felicity Judgment task, however, does not involve the presentation of the basic and the derived interpretation of a target sentence (e.g., *Every farmer cleaned a horse or a rabbit* and *Every farmer cleaned a horse or a rabbit and it is not the case that every farmer cleaned a horse <u>and</u> a rabbit*). It is possible that the assertion of an alternative sentence like *Every farmer cleaned a horse and a rabbit* might help the child to use such sentence in the construction of the implicature for *Every farmer cleaned a horse or a rabbit*. An alternative explanation about the effect of

the presentation of the two sentences is equally possible, however. In particular, the presentation of two sentences could make it unnecessary for the child to carry out the computation, since information strength suffices to discriminate between the two assertions. On this view, the presentation of two sentences that are both true in the context under consideration would lead the child to base her decision on something other than the truth of the target sentence. In absence of more research on children's interpretation of other scalar terms in different linguistic contexts, and in absence of more research on the kinds of phenomena that can be investigated with the Felicity Judgment task, it is difficult to see how these hypotheses could be tested. Despite the lack of an explicit characterization of the kind of processing limitations that children experience, the Processing Limitation hypothesis leads to an important prediction. The variant of the Processing Limitation hypothesis proposed by Chierchia et al. (2001) assumes that the failure to compute scalar implicatures is due to children's limited resources. Therefore, the Processing Limitation hypothesis predicts that scalar implicatures should always be computed by subjects whose working memory does not suffer the same limitations. In other words, adults' interpretation of sentences containing a scalar term should always be determined by the result of the local comparison assumed by the Semantic Core model.

To sum up, the findings of the Chierchia et al. study provide empirical support for the Semantic Core model. The difference in children's and adults' computation of scalar implicatures, however, calls for further research. In particular, it remains to be shown whether the phenomenon under investigation is restricted to child language. In order to conclude that the source of children's non-adult responses to sentences containing a scalar term in a *non*-DE environment is due to their limited working memory, it is important to test subjects who do not present the same working memory limitations. A natural way to evaluate this hypothesis is to consider whether adult's interpretation of sentences containing a scalar term is always influenced by scalar implicatures. In section 3.3 we report the results of two experiments designed to investigate how consistently adult speakers of English reject a sentence that is true on its basic interpretation, simply because a more informative statement is available.

## 3 Experimental Investigations on the Interpretation of Scalar Terms in the Nuclear Scope of *None of the Ns*

In this section we present the results of four experiments investigating children's and adults' interpretation of scalar terms within a particular DE context. The linguistic context considered in the experiment is the nuclear scope of

quantificational phrases of the form *None of the Ns*.[40] The nuclear scope of such quantificational phrases is downward entailing. First, sentences containing a quantified phrase like *None of the Ns* license inferences from a set to its subsets, as shown in (72).

(72) None of the students wrote a paper yet ⇒ None of the students wrote a good paper yet.

Second, negative polarity items are licensed in the nuclear scope of *None of the Ns*, as shown in (73).

(73) a. None of the students wrote any paper.
b. None of the students ever wrote a paper.

Finally, the interpretation of sentences containing disjunction in the scope of the quantificational expression *None of the Ns* conforms to the De Morgan's law discussed earlier (see section 1.3).

(74) None of the students wrote a paper or made a presentation yet ⇒ None of the students wrote a paper yet, and none of the students made a presentation yet.

Given its DE properties, the nuclear scope of the quantificational phrase *None of the Ns* provides a context to investigate some of the questions that have been left unanswered by previous research.[41]

The Semantic Core model maintains that scalar implicatures do not arise if a scalar term occurs in the scope of a downward entailing operator, and this claim has been supported by the results obtained by Chierchia et al. (2001). The Semantic Core model, however, predicts that the same results should obtain for any DE environment. Experiment 1 was designed to provide additional evidence in favor of the Semantic Core model, investigating the accessibility of the inclusive-*or* interpretation of the disjunction operator in another DE environment, namely the nuclear scope of the quantified expression *None of the Ns*.

As we have seen in section 2.2, previous research on children's knowledge of downward entailment has shown that children do not interpret sentences

[40] We will not be concerned with the partitive character of the quantified expression under investigation. The only reason why we decided to use *None of the Ns* instead of *No* was that the use of the partitive phrase seemed slightly more natural for English speakers.

[41] A detailed description of the syntactic structure of sentences containing coordinated phrases is beyond the scope of the present studies. In our analysis, we will simply assume that coordination takes place at the sentential level.

containing disjunction in the scope of a *non*-DE operator in accordance with the inferential scheme typical of downward entailing environments (cf. Boster and Crain, 1993). These studies, however, have not addressed the reverse question, namely whether children interpret sentences containing disjunction in the scope of a DE operator in accordance with the inference scheme typical of most *non*-DE environments. Experiment 2 was designed in order to fill this gap.

Adults' interpretation of sentences containing the conjunction *and* in the nuclear scope of the quantified expression *None of the Ns* is investigated in Experiments 3 and 4. As we have observed in section 1.4, the Semantic Core model predicts that the relative information strength of sentences containing a scalar term in the scope of a downward entailing operator is reversed. In short, a sentence of the form $OP_{DE}$*(A or B)* is more informative than $OP_{DE}$*(A and B)* in a context in which both $OP_{DE}$*(A)* and $OP_{DE}$*(B)* are true.[42] Furthermore, the Semantic Core model predicts that the hearer of $OP_{DE}$*(A and B)* should compute an implicature, such that the sentence is interpreted as $OP_{DE}$*(A and B) and not* $OP_{DE}$*(A or B).* For example, upon encountering a sentence like *John does not like pizza and ice cream*, the hearer should compute an implicature and obtain a derived interpretation of the form *John does not like pizza and ice cream and it is not the case that he does not like pizza or ice cream.* Importantly the derived interpretation of the target sentence suggests that John does not like both pizza and ice cream, but he does like one of the two. This makes the sentence *John does not like pizza and ice cream* infelicitous in a context in which it is known that John does not like pizza and he does not like ice cream. Experiment 3 was designed to investigate whether adult speakers of English reject a sentence like $OP_{DE}$*(A and B)* in a contexts in which both $OP_{DE}$*(A)* and $OP_{DE}$*(B)* are true. Experiment 4 was conducted to determine if adult speakers of English judge the use of disjunction more felicitous than the use of conjunction in the same context. Let us consider each experiment in detail.

### 3.1 Children's and Adults' Interpretation of Disjunction in the Nuclear Scope of *None of the Ns*

The Semantic Core model maintains that the licensing of *any* and the computation of scalar implicatures are governed by the same principles (see Chierchia, 2000). On the Semantic Core model, scalar implicatures fail to arise in a range of

[42] Strictly speaking, a sentence of the form $OP_{DE}$*(A or B)* is always more informative than $OP_{DE}$*(A and B)*. As we did for sentences of the form *A and B* and *A or B*, however, we assume that relative information strength of two sentences only plays a role when both sentences are true. Taking sentences of the form $OP_{DE}$*(A or B)* and $OP_{DE}$*(A and B)*, such case obtains when both $OP_{DE}$*(A)* and $OP_{DE}$*(B)* true.

linguistic contexts, because of the semantic property of downward entailment, which in turn is part of the meaning of many expressions of natural languages. As a consequence, children are expected to cancel scalar implicatures for any downward entailing operator occurring in their speech. This section presents the findings of an experiment designed to investigate this prediction, taking the implicature of exclusivity associated with disjunction as a case study.

Given the downward entailing properties of the nuclear scope of the quantificational phrase *None of the Ns*, the Semantic Core model predicts that the implicature of exclusivity for disjunction will not arise for sentences like (75).

(75) None of the students wrote a paper or made a presentation.

Again, the prediction that the disjunction operator receives an inclusive-*or* interpretation in (75) is confirmed adults' intuitions. In particular, adult speakers of English judge the sentence in (75) false if some student both wrote a paper and made a presentation. To evaluate if English-speaking children also interpret sentences like (75) on the basic inclusive-*or* interpretation of disjunction, we designed an experiment using the Description Mode of the Truth Value Judgment task. Let us consider one of the trials of the experiment.

(76) "This is a story about three monkeys and a Bunny Rabbit. The monkeys are taking a nap. They have left all their stuff here: see, there are three slices of grapefruit, a banana and a Frisbee. While the monkeys are sleeping, the Bunny Rabbit comes over, and he says: "Oh! The monkeys are sleeping and they have left all their stuff here! I want to tease them a little bit, so I will hide all this stuff up in those trees!" and the Bunny Rabbit hides the grapefruit, the banana and the Frisbee on the branches of three trees. A few moments later, the monkeys wake up and they realize that all their stuff is gone. They see Bunny Rabbit who is watching them from behind a tree, and they realize it must have hidden their stuff somewhere, most likely in the trees. The first monkey says: "Well, that's not a big deal! Everybody knows that monkeys are very good at climbing trees, so I am sure we can get all our stuff back very easily! I hope we can get the banana back, and I hope we can get the Frisbee back, because I really feel like eating a banana and playing with the Frisbee now!" The monkey walks towards a tree, and when it is close enough, the monkey sees a slice of grapefruit and grabs it, saying "I did not find the Frisbee and I did not find the banana, but I like grapefruit, so this is not too

bad." The second Monkey says: "Don't worry, I will do better than that!" and it starts climbing one of the trees. When the monkey gets on the top of the tree, it finds a slice of grapefruit. After grabbing the grapefruit, the second monkey says: "Too bad! I could not find the banana and I could not find the Frisbee! Of course I like grapefruit, but I hope that the Bunny Rabbit has not taken away the rest of our stuff." The third monkey says: "Don't worry! I'm sure I will be able to get the banana! Maybe I can get the Frisbee!" The third monkey starts climbing the last tree, and it gets on the top of the tree on which the Bunny Rabbit has put the banana and the Frisbee, but the monkey does not notice them because they are covered by leaves, so it just grabs some grapefruit, and starts complaining: "I can't believe Bunny Rabbit did this to us, now we can't eat our banana and we will not be able to play with our Frisbee!" At this point, the first monkey says: "Well, I guess I have been a bit lazy, and I did not climb any tree, so why don't I give it one more try?" and it starts walking towards the trees, and after looking at all the trees it climbs on the tree where Bunny Rabbit hid the banana and the Frisbee, it finds the Frisbee and the banana and all three monkeys start cheering."

At this point, the puppet Kermit the Frog uttered the target sentence, preceded by the linguistic antecedent.

(77) I liked this story about a Bunny Rabbit and some monkeys and I think I know what happened. Every monkey found some grapefruit, but <u>none of the monkeys found the banana or the Frisbee</u>.[43]

Let us focus on the target sentence, namely the clause containing the scalar term *or* (i.e., *none of the monkeys found the banana or the Frisbee*, in the example above). It is important to notice that the truth-value of such sentence depends on whether SIs are computed or ignored. In particular, if scalar implicatures are computed, the target sentence would be interpreted as (78a), whereas if scalar implicatures are not computed, the interpretation would be (78b).

[43] The sentence uttered by the puppet is longer than optimal. In particular, the (underlined) target sentence is preceded by the description of what every monkey had found. This maneuver does not directly affect the interpretation of the target sentence, but turned out to be a crucial factor for the felicity conditions of the target sentence itself. We consider this issue in more detail in section 3.2.

(78) a. None of the monkeys found the banana or the Frisbee, and it is not the case that none of the monkeys found the Frisbee and the banana.[44]
b. None of the monkeys found the banana, and none of the monkeys found the Frisbee.

In accordance with the design of the Truth Value Judgment task, the context set up by the story above discriminates between the two interpretations in (78). In particular, the interpretation paraphrased in (78a), obtained upon computing SIs, is true in the present context, since none of the monkeys found only one object (in fact, two monkeys did not find either one, and one monkey found both the Frisbee and the banana). By contrast, the basic interpretation in (78b) is false, because one monkey found both the Frisbee and the banana. In other words, the fact that one monkey found both the Frisbee and the banana falsifies the target sentence under the interpretation in (78b), but not under the interpretation in (78a). Setting up the context so that the target sentence receives a different truth-value depending on which interpretation is adopted allows the experimenter to infer which interpretation underlies the child's response.[45]

Let us consider the results. Fifteen children (age from 3;09;00 to 5;08;05; mean age: 4;3;19) participated in the experiment. Each child was presented with four target trials, preceded by a warm-up trial, and interspersed with filler sentences in order to balance the number of 'yes' and 'no' answers. Out of the 60 trials, children correctly rejected the target sentence 55 times (92%). Importantly, when children were asked to motivate their answer, by telling the puppet "what really happened in the story," they pointed out that the puppet was wrong because

[44] Let us try to illustrate what this reading amounts to. Intuitively, the contribution of the basic interpretation of the target sentence (i.e., *None of the monkeys found the banana or the Frisbee*) requires that the none of the monkeys found the Frisbee and that the none of the monkeys found the banana. By contrast, the alternative statement *None of the monkeys found the banana and the Frisbee* is true if (a) some monkey found either the Frisbee or the banana or (b) if all the monkeys failed to find these objects. Let us consider the negation of this alternative sentence, i.e., *it is not the case that none of the monkeys found the Frisbee and the banana*. Intuitively, for this sentence to be true, at least one monkey must have both the banana and the Frisbee. Therefore, adding the implicature *it is not the case that none of the monkeys found the Frisbee and the banana* to *None of the monkeys found the banana or the Frisbee* we obtain an empty set. In fact, one sentence requires that none of the monkeys found anything, and the other sentence requires that some monkey found both objects. Since the computation of the implicature does not lead to a more informative statement, the sentence is evaluated on the inclusive-*or* interpretation of the disjunction operator. This makes the sentence false in a context in which one monkey found both the Frisbee and the banana.

[45] An important feature of the experimental design requires that the adult interpretation is associated with a negative answer, so that children's bias to respond affirmatively acts against the response dictated by the child's grammar. Again, we refer the reader to Crain and Thornton (1998) for a discussion of these experimental details.

one of the monkeys had found both the Frisbee and the banana. Eleven English-speaking adults were tested as adult controls using a video-taped version of the experiment. Out of the 44 trials, they always rejected the target sentence. In short, children as well as adults consistently accessed the full range of truth conditions associated with the inclusive-*or* when the disjunction operator occurred in the nuclear scope of the quantificational expression *none of the Ns*, a DE environment. These results are perfectly explained by Chierchia's account, and illustrate another downward entailing context in which scalar implicatures fail to arise. Importantly, a simple modification of the protocol employed in Experiment 1 allows us to investigate children's knowledge of the logical properties of Downward Entailment. This issue was addressed in a second experiment, which is described in next section.

### 3.2 Children's and Adults' Knowledge of the Logical Properties of the Nuclear Scope of *None of the Ns.*

This experiment tested children's knowledge of one of the logical properties of downward entailment. As we have observed in section 1.3, the interpretation of the disjunction operator in the scope of a downward entailing operator conforms to the following scheme:

(79) $OP_{DE}(A \text{ or } B) \Rightarrow OP_{DE}(A) \text{ and } OP_{DE}(B)$

The present experiment was designed to investigate if young children know that the interpretation of a sentence containing the disjunction operator in the scope of the quantified expression *none of the Ns* must conform to the scheme in (79). Let us review how (79) accounts for the interpretation of sentences containing the disjunction operator *or* in the scope of *None of the Ns* in English. Consider:

(80) None of the students wrote a paper or made a presentation.

This sentence gives rise to the inference in (81a), but not to the one in (81b):

(81) a. None of the students wrote a paper <u>or</u> made a presentation $\Rightarrow$ None of the students wrote a paper, <u>and</u> none of the students made a presentation.
b. None of the students wrote a paper <u>or</u> made a presentation *$\Rightarrow$ None of the students wrote a paper <u>or</u> none of the students made a presentation.

It is important to observe that the interpretation of the disjunction operator in the scope of many *non*-DE operators gives rise to the opposite pattern:

(82) a. Some of the students wrote a paper or made a presentation *⇒ Some of the students wrote a paper, and some of the students made a presentation.
b. Some of the students wrote a paper or made a presentation ⇒ Some of the students wrote a paper or some of the students made a presentation.

Now, suppose a child learned how to interpret sentences containing the disjunction operator by generalizing from other sentences with similar surface form. If this were the case, then we would expect some children to assign a wrong interpretation to sentences like (80). In particular, we would expect children to accept such sentence in a situation in which only one of the disjuncts in (81b) is true. By contrast, if children obeyed the logical property of downward entailment, we would expect their interpretation of sentences like (80) to conform to the scheme in (79). In short, children would not construct a wrong generalization on the basis of the interpretation of *or* in most *non*-DE environments, and would use the same interpretation as adults. To distinguish between these two hypotheses, we designed an experiment employing the Truth Value Judgment task.

As we have seen in describing Experiment 1, the design of the Truth Value Judgment task requires a context that falsifies the adult interpretation of the target sentence, and verifies the non-adult interpretation under investigation. Let us illustrate how this feature of experimental design was satisfied in the present experiment. In one of the trials, children were told the following story.

(83) "This is a story about an Indian who is going to shop for groceries. The Indian has heard that some pirates have been surprised stealing in a camp nearby, so he decides to hide all his things before he leaves. In particular he wants to hide three knives, a golden necklace and a jewel. He is really concerned about the jewel and the golden necklace, because he received them as a gift from a dear friend of his. He puts each object in a barrel and he leaves. After he leaves, three pirates arrive. One pirate says: "Look, an Indian camp! There is always a lot of stuff to steal in an Indian camp! I am sure we will find something valuable, like a jewel. Maybe even a golden necklace!" and he takes one of the barrels. He looks inside and finds a knife. A second pirate says: "Oh, just a knife! Well, I'll see if I can find something better. Maybe I can find a jewel, or maybe I can find a necklace." He takes one barrel, and when he looks inside he finds another knife.

> The third pirate says: "Oh! you guys were not lucky at all! I am sure there is something better to steal here. I'll go now!" The third pirate takes a third barrel. When he looks inside the barrel, however, he finds another knife. The pirates are very disappointed, and they are ready to leave because they know the Indian is about to come back. But one pirate says: "Hey, I can't believe we haven't been able to find anything better than knives. I will go back one more time and see what I can find!" He runs back to the Indian camp and he takes another barrel. When he looks inside he finds a jewel, and says: "See! I told you it was worth going back one more time! Now we can leave."

At this point the puppet uttered the target sentence, preceded by the linguistic antecedent, as in (84).

(84) This was a story about an Indian and some pirates and I know what happened. Every pirate found a knife, but <u>none of the pirates found the jewel or the necklace</u>.

Notice that the target sentence is false on the (only) interpretation licensed by the grammar (i.e., 85a), but it is true on the interpretation that is not licensed by the grammar, and which could be constructed by analogy from *non*-DE environments (i.e., 85b)

(85) a. None of the pirates found the jewel <u>and</u> none of the pirates found the necklace.
b. None of the pirates found the jewel <u>or</u> none of the pirates found the necklace.

The experimental hypothesis was that children would consistently reject the target sentence, because of the downward entailing properties of the nuclear scope of the partitive headed by *none*.

Let us consider the results. Fifteen children (age from 3;10;26 to 5;08;04 mean age: 4;6;16) participated in the experiment. Each child was presented with four target trials, preceded by a warm-up trial, and interspersed with filler sentences. In the design of the experiment, we also controlled for a possible order effect.[46] Out of the 60 trials, children correctly rejected the target sentence 50 times (83%). Importantly, when the puppet asked children "what really happened

[46] In two of the trials the sentence was false because the first conjunct of the adult interpretation was false, just like in the story described above; in the remaining two trials, the target sentence was false because the second conjunct was false.

in the story," they pointed out that the puppet was wrong because one of the pirates had actually found the jewel. A control group of 28 English-speaking adults were tested using a video-taped version of the experiment. Adults correctly rejected the target sentence on 99% of the trials.

It is worth discussing the details of the experiment.[47] In particular, we need to explain why children's rejection did not reach the percentage that we usually require in order to support the experimental hypothesis (i.e., 90%). While describing Experiment 1, we have already noticed that the target sentence is longer than optimal. In particular, the sentence under consideration (*None of the pirates found the jewel or the necklace*, in the story above) is preceded by another statement about what they had found (*Every pirate found a knife*). This choice was dictated by children's behavior in the first stage of the execution of the experiment, during which the non-adult responses were recorded and during which the puppet did not mention what the pirates had found. Interestingly, children's unexpected acceptance of the target sentence was accompanied by a comment about what the characters in the story had done (e.g., "They found a knife!"). In our view, such a comment indicated that the child was focusing on what had happened in the story, even though the target sentence focused on what had failed to happen. Intuitively, children were expecting the puppet to describe what the pirates had found, but the target sentence did not fulfill such expectation. This hypothesis suggested to us that children's affirmative answer were due to the failure to satisfy the felicity conditions associated with a negative statement.[48] To overcome this potential confounding factor, we decided to use a more elaborate linguistic antecedent. In particular, we thought that if the puppet itself had specified that the pirates had found a knife and then what they had not found, children would focus on the target sentence. In this way, in fact, the puppet would describe the entire contents of the story. The individual results obtained with the (four) children who were presented with the more elaborate linguistic antecedent are consistent with this prediction. Notice that if the 'yes' responses given by the children who were not presented with the longer linguistic antecedent were dictated by the non-adult interpretation in (85b), the use of a longer linguistic antecedent should have made no difference.

A second issue that needs to be addressed is the difficulty of the construction under consideration. It must be observed that the target sentences

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[47] In the following paragraphs we refer to both Experiment 1 and Experiment 2.

[48] Children's interpretation of sentences containing quantified expressions headed by *No* or *None of the Ns* has not been investigated in great details by previous studies Previous research on children's understanding of sentences involving negation has not reported this kind of difficulty in children's responses. It is therefore possible that the difficulty experienced by the children who participated in Experiments 1 and 2 results from the interaction between the use of a negative-like statement and the particular quantifier we used.

turned out to be quite difficult for the children we interviewed.[49] A complete account of children's understanding of the quantified expression *None of the Ns* is beyond the scope of the present study. It is worth pointing out, however, that many children could not repeat the target sentence uttered by the puppet, despite their adult-like judgments of the puppet's assertion. On several occasions, after the child had said whether the puppet was right or wrong, the first experimenter asked the child to repeat what the puppet had said, saying something like: "Oh you were paying very close attention to this story! I was not listening, so I would like you to tell me what he said about the story." Surprisingly, most of the children who responded to such request systematically modified the target sentence. To illustrate, if the puppet had produced the target sentence in (86), children were very likely to report his assertion as (87).

(86) None of the pirates found the jewel or the necklace.

(87) Every pirate didn't find the jewel or the necklace.

Notice that (86) and (87) are both false in the context set up by the experiment, and in both cases the disjunction operator occurs in a downward entailing environment. As a consequence, the particular context we used did not discriminate between the two interpretations in (86) and (87). More research is needed, however, to investigate children's interpretation of quantified expressions of the form *None of the Ns*. Two issues immediately arise. First, one needs to determine if children's difficulties with quantified expressions of the form *None of the Ns* lead to a non-adult behavior in particular contexts. Second, one should investigate what lies beneath children's choice of (87) as a paraphrase of (86), and why (87) was used instead of another possible paraphrase (i.e., *There isn't a pirate who found the jewel or the necklace*).

In this section we described the design and the results of an experiment investigating children's knowledge of the logical properties of downward entailment. The findings show that children as well as adults interpret sentences containing disjunction in the nuclear scope of the quantificational expression *none*

[49] Incidentally, this is one of the reasons why our youngest subject was 3;10. It is important to observe that the study by Boster and Crain (1995) which investigated children knowledge of the logical properties of *non*-DE environments tested children ranging in age from 3;6 to 6;0, with a mean age of 4;8. Also Conway and Crain (1995) used sentences containing these quantified expressions in a study investigating children's knowledge of discourse anaphora, and they interviewed "fifteen three-to-five year old children" (Conway and Crain, 1995; p. 190). Sentences containing the determiner *no* were also used in an experiment investigating children's knowledge of Principle B conducted by Savarese (1999). The children who participated in the experiment conducted by Savarese (1999) ranged in age from 4;3 to 6;4.

*of the Ns*, a DE environment, in accordance with the logical properties of downward entailment.

### 3.3 The Reversion of the Scale in Downward Entailing Contexts

As we have argued in Section 2.1 and 2.3, previous research on children's knowledge of scalar implicatures has failed to show a consistent computation of scalar implicatures in young children across all experimental conditions. In an attempt to minimize the differences between child language and adult language, Chierchia et al. (2001) advanced the hypothesis that children's behavior in particular experimental conditions might result from processing limitations, rather than lack of pragmatic knowledge. Consistently with this hypothesis, the results of an experiment employing the Felicity Judgment task have been interpreted by Chierchia et al. (2001) as showing children's pragmatic knowledge when the task consists in choosing between two alternative sentences, which logically have the same truth-value in a given situation.

The Processing Limitation hypothesis has much to recommend it. In particular, the Processing Limitation hypothesis maintains that children and adults share the same linguistic competence. In other words, children's pragmatic knowledge is intact. The computation of scalar implicatures, however, requires the execution of a comparison between two alternative representations of a sentence. Importantly, this comparison imposes considerable demands on the child's limited working memory. The processing Limitation hypothesis proposed by Chierchia et al. (2001) constitutes a viable explanation of children's behavior documented by previous research. Despite its plausibility, the Processing Limitation hypothesis suffers some difficulties.

On the pre-theoretical level, the Processing Limitation hypothesis is not entirely consistent with the strongest version of the Continuity hypothesis (Pinker, 1984; Crain and Thornton, 1998). In particular, Crain and Thornton (1998) argued that children and adults also share the same language processing system. Here is how they put it: "Moreover, any account of children's performance that attributes different properties to the child and the adult processing system must face a new question: how does the processing system of the child change as to converge on the adult system? To the extent that the cognitive mechanisms of children and adults are similar, problems of learnability do not arise."[50] A second drawback of the Processing Limitation hypothesis put forth by Chierchia et al. (2001) is the lack of an explicit characterization of the way children's behavior is influenced by their limited working memory resources. In other words, attributing children's

[50] Crain and Thornton (1998; p. 30).

non-adult responses to processing limitations only constitutes a first step towards an explanation of the differences between child and adult language.

In this section, we investigate adults' interpretation of sentences containing the conjunction operator *and* in the nuclear scope of *None of the Ns*. The purpose of these experiments is to investigate if adults also refrain from computing (or acting in accordance to) scalar implicatures in particular experimental contexts. The results of these experiments are not intended to disconfirm the Processing Limitation Hypothesis. More simply, we believe that the findings of these experiments would need to be taken into account if one wants to evaluate the extent to which children's failure to compute scalar implicatures denote non-adult pragmatic knowledge.

### 3.3.1 Adults' Interpretation of Conjunction in the Nuclear Scope of *None of the Ns* - A Truth Value Judgment Task

The Semantic Core model maintains that the relative information strength of sentences containing scalar terms is reversed in downward entailing contexts (see Section 1.4). In short, any term that yields the more informative statement in a *non*-DE contexts will yield the less informative statement in DE context. As an additional example consider (88).

(88) None of the students wrote a paper and made a presentation yet.

Under its basic interpretation, (88) is true in the following range of circumstances:

(89) $situation_1$ = None of the students wrote a paper, but some student made a presentation.
$situation_2$ = None of the students made a presentation, but some student wrote a paper.
$situation_3$ = None of the students wrote a paper, and none of the students made a presentation.

Since (88) contains a scalar term, its basic interpretation must be compared with a derived interpretation, resulting from the conjunction of (88) with the negation of the alternative statement containing *or*.

(90) None of the students wrote a paper and made a presentation yet, and it is not the case that none of the students wrote a paper or made a presentation yet.

The second conjunct in (90) is true in the following range of circumstances:

(91) $situation_1$ = None of the students wrote a paper, but some student made a presentation.
$situation_2$ = None of the students made a presentation, but some student wrote a paper.
$situation_4$ = Some student wrote a paper and some student made a presentation.

Intersecting the sets in (89) and (91) we obtain the set of circumstances that verify the derived interpretation of (88), namely:

(92) $situation_1$ = None of the students wrote a paper, but some student made a presentation.
$situation_2$ = None of the students made a presentation, but some student wrote a paper.

Since the set of circumstances in (92) constitutes a subset of the circumstances in (89), the derived interpretation in (90) is informationally stronger, and must be adopted for the interpretation of the sentence *None of the students wrote a paper and made a presentation*. Crucially, such an interpretation makes the sentence infelicitous in a context in which no student wrote a paper and no student made a presentation. As a result, speakers of English should reject (88) in the context under consideration, for the very same reason they reject a sentence of the form *A or B* when both *A* and *B* are true.

To investigate adults' interpretation of sentences like (88), we designed a third experiment adopting the Truth Value Judgment task. The subjects were presented with stories similar to the ones employed in Experiments 1 and 2. Consider one of the trials.

(93) "This is a story about three polar bears who are getting bored, because they do not have any toy to play with. While they are looking for something to play with, the polar bears see Donald Duck who is carrying a wagon full of toys. The polar bears ask Donald Duck if they could borrow some of their toys, and Donald Duck says: "Sure! I have three skate-boards, I have a basketball, and I have a Frisbee. You can definitely borrow the skate-boards, but I would like to keep the basketball and I would like to keep the Frisbee, because I was planning to play with them." Two polar bears are very happy about Donald Duck's offer, and each one of them takes a skate-board from

> Donald Duck. The third polar bear takes the last skate-board, but it is not really happy, so it says: "You know, Donald Duck, it is very nice of you, but I am not crazy about skateboards, and I would really love to use your basketball," and it gets closer to Donald Duck's basketball. But Donald Duck says "Hey, no! I told you I wanted to play with this basketball, so I do not want you to take it!" The third polar bear then says: "Ok, ok! Don't get mad at me. I'll just use the skate-board then." So, in the end each polar bear plays with a skate-board."

At this point, the subjects were presented with the target sentence in (94):

(94) Every polar bear chose a skate-board, but none of the polar bears chose the Frisbee and the basketball.

The use of the conjunction *and* in the nuclear scope of the *None of the Ns*, a DE environment, should raise scalar implicatures. If adults computed the scalar implicature associated with *and*, they should reject the target sentence, and point out that (95) is a more accurate description of the story.

(95) None of the polar bears chose the Frisbee or the basketball.

Importantly, the subjects who participated in this experiment were instructed to reject wrong statements, as well as statements that were just perceived as infelicitous. In other words, subjects were explicitly told that the infelicity of a sentence constituted an appropriate reason to reject such sentence.

Fifteen English-speaking undergraduates participated in the experiment. These subjects accepted the puppet's statement 54 times out of 60 trials (90%).[51] Importantly the cases of rejection were not motivated by the detection of the pragmatic anomaly (i.e., the calculation of the implicature). All such responses occurred at the end of the particular story we described, and were motivated by the fact that adults thought the third polar bear had actually chosen the basketball, although in the end the bear could not play with the basketball because Donald Duck had decided to keep it for himself. Only one subject pointed out that an alternative statement like (95) would also constitute a possible description of the story, but this was not enough for the subject to reject the target sentence in any of the target trials.

[51] Four of the subjects who participated in the experiment were not native speakers of English. If one excludes the responses provided by these non-native speakers, the results are limited to eleven subjects who accepted the target sentence in 39 trials out of 44 (89%).

These results show that English-speaking adults fail to detect the violation of scalar implicatures constituted by the use of the conjunction *and* in a context in which *or* would be more appropriate, in a way that closely resembles the behavior of some children in Experiment 2 of the Chierchia et al. study. In our view, such results show that adults refrain from applying scalar implicatures in particular experimental contexts. The claim that adults' judgments are not always guided by the computation of scalar implicatures also suggests that children's strictly logical behavior revealed by previous research does not necessarily denote lack of pragmatic knowledge. Moreover, if we concede that adults sometimes fail to apply scalar implicatures, we can maintain the claim that scalar implicatures are computed in the same way in downward entailing and *non*-DE contexts. A potential weakness of such hypothesis, however, comes from the fact that no adult rejected the target sentence. This leaves us with no experimental evidence that the information strength associated with alternative representations of the target sentence yields a reversed scale in downward entailing contexts. To address this potential problem, we conducted an experiment using the Felicity Judgment task, the experimental technique that was devised by Chierchia et al. to reveal children's knowledge of scalar implicatures. The findings of this experiment are reported in the next section.

### 3.3.2 Adults' Interpretation of Conjunction in the Nuclear Scope of *None of the Ns* – A Felicity Judgment Task

In the previous section we have shown that adults fail to compute (or at least fail to behave in accordance with) scalar implicatures when engaged in a Truth Value Judgment task with sentences containing the conjunction operator *and* in the nuclear scope of the quantified expression *None of the Ns*. A follow-up experiment was conducted with a different group of adult speakers of English, adopting the Felicity Judgment task. As we have seen in section 2.3, this methodology involves the presentation of two target sentences to the subject, who is asked to indicate which sentence constitutes a better description of the context under consideration.

Let us illustrate one of the trials of this experiment.

(96) "This is a story about three dolphins, three dogs, a penguin and a panda bear. The dolphins are swimming in the ocean, and they decide to rest a little bit on the shore. When they arrive close to the seashore, they find three dogs, one panda bear and one penguin looking at them. One of the dogs says: "Hey, I heard you dolphins are very good swimmers, and that you can even take other animals for a ride. Is that true?" One of the

dolphins, says: "Sure, if you want we could take some of you for a ride, would you like that?" The dogs, the panda bear and the penguin are all very excited, and they invite the dolphins to choose one animal. The three dolphins look at the other animals, and they all agree that the penguin and the panda bear are too fat and heavy for them, so each dolphin decides to carry one dog. They swim for a little while with the dogs on their backs, and they get back to the shore. At this point, one of the dolphins says: "I feel very sorry for the penguin and the panda bear, because nobody took them for a ride. The panda bear is really fat, but maybe I could give a ride to the penguin," and it starts swimming towards the penguin, but then the dolphin says: "You know, actually, you are pretty fat too! I am sorry, I don't think I can take you for a ride."

At this point, subjects were asked to choose which of the following sentences constituted a better description of the story.

(97) Every dolphin carried a dog, but none of the dolphins carried the penguin or the panda bear.

(98) Every dolphin carried a dog, but none of the dolphins carried the penguin and the panda bear.

Let us look at the results. Sixteen adult speakers of English participated in the experiment, which included four target trials. Out of the 64 trials, however, the subjects expressed a preference on only 32 trials.[52] Out of these 32 trials, the adult subjects chose the sentence containing the disjunction operator *or* as the most accurate description in 28 cases (87.5%). It is not entirely clear why adults refrained from making a choice in half of the trials. When a choice was made, however, the rate of preference for sentences like (97) is consistent with the claim that the use of disjunction in the scope of a Downward Entailing operator is more informative than conjunction.

[52] Only 5 subjects expressed a preference for all four target trials. Here is the complete distribution of the results: 4 subjects never expressed a preference, 5 subjects always expressed a preference, two subjects expressed a preference in only one case, and two subjects expressed a preference in three cases. The remaining three subjects only expressed a preference on two of the target trials.

### 3.3.3 Adults' Interpretation of Conjunction in the Nuclear Scope of *None of the Ns*

Taken together, the results from Experiments 3 and 4 show that in a particular linguistic context adult speakers of English accept a sentence of the form $OP_{DE}$*(A and B)* in a situation in which such sentence is logically true, although they know that in the same context a sentence of the form $OP_{DE}$*(A or B)* would be more informative. It remains to be determined whether adults' adherence to the basic interpretation of scalar terms extends beyond the interpretation of the conjunction *and* in the nuclear scope of the quantified expression *None of the Ns*. Two factors could be responsible for the results we obtained: the pairs of scalar terms we chose, or the particular linguistic environment we used. A natural follow-up suggested by Stephen Crain (p.c.) would be a Truth Value Judgment task investigating the interpretation of the scalar terms *some* vs. *many*. Consider the sentences in (99).

(99) a. The first year students are expected to write some papers.
b. The first year students are expected to write many papers.

Because of scalar implicatures, (99b) is the most felicitous description of a context in which the students under consideration are expected to write a considerable number of papers. Now suppose that it is known that first-year students are not expected to write any papers. In this context, the more felicitous sentence is constituted by (99a), which contains the NPI-counterpart of *some* (i.e., *any*).

(100) a. None of the students is expected to write any papers.
b. None of the students is expected to write many papers.

At first glance, it seems that in this case adult speakers of English would occasionally reject (100b) since it raises the implicature that the students must in fact write some paper. More research is needed in order to show that adults compute the implicature associated with *many* in downward entailing contexts. In absence of more experimental evidence, however, one should bear in mind that the clearest cases of difference between children and adults in positive contexts are constituted by the interpretation of the disjunction *or*.

To recap, the findings reported in this section show a linguistic context in which adult speakers of English do not compute scalar implicatures. We are not in the position to provide a conclusive interpretation of these findings. It remains to be explained why the particular linguistic context we considered produced this effect, and it remains to be explained why children fail to compute scalar

implicatures in far simpler contexts. In light of the results described in this section, however, one should be cautious in concluding that the failure to respond on the basis of the implicature necessarily denotes lack of pragmatic knowledge. Experimental data from young and adult subjects suggest that this reasoning is unwarranted.

## 4 Conclusion

This paper reported the findings of four experiments investigating pragmatic and semantic competence in adults and young children. In particular, we investigated the interpretation of the logical words *or* and *and* in the nuclear scope of the quantificational expression *None of the Ns*, a downward entailing environment.

The results of two experiments investigating child language corroborate the findings from previous research in two ways. First, we have provided more experimental evidence in favor of the Semantic Core model, showing yet another context in which scalar implicatures fail to arise, regardless of the amount of information available to the speaker. Second, we have shown that children's knowledge of downward entailment extends beyond the licensing and the interpretation of negative polarity items, and includes the logical properties of downward entailment.

The results of the two experiments investigating adult's computation of scalar implicatures shed a new light on the finding of previous research. As we have repeatedly observed, previous research has revealed some differences in children's and adults' computation of scalar implicatures. In short, children's behavior documented in previous research conformed to the logical interpretation of scalar terms rather than to the interpretation obtained through the computation of scalar implicatures. The results of two experiments investigating adults' interpretation of sentences containing the scalar term *and* in the scope of *None of the Ns* provided us with a context in which adults adhere to logic, in a way that closely resembles children's behavior reported in previous studies.

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