Handbook of Generative Approaches to Language Acquisition
Studying Language Acquisition Through the Prism of Isomorphism

Julien Musolino

1 Introduction

A topic that has received an enormous amount of attention on the part of scholars interested in natural language semantics is the phenomenon of linguistic quantification. Over the last decade, a growing number of studies on the acquisition of semantics have focused on the way children interpret sentences containing quantified NPs and negation (Musolino 1998, 2006a, b; Musolino et al. 2000; Lidz and Musolino 2002, 2005; Musolino and Lidz 2003, 2006; Musolino and Gualmini 2004; Gualmini 2004, 2008; Gualmini et al. 2008; Krämer 2000; Noveck et al. 2007; Gennari and MacDonald 2005/2006; O’Grady 2008; Conroy 2008; among others). Much of this work grows out of an observation by Musolino (1998) that preschoolers, unlike adults, display a strong preference for the interpretation of such sentences that corresponds to the surface syntactic position of the quantificational elements involved. Consider for example, the sentence in (1) which contains the quantified NP Every horse and negation. On one reading, (1) can be paraphrased as meaning that every horse is such that it did not jump over the fence; in other words, none of the horses jumped, (1a). Alternatively, (1) can be paraphrased as meaning that not all the horses jumped over the fence, (1b).

(1) Every horse didn’t jump over the fence
(a) None of the horses jumped over the fence
(b) Not all the horses jumped over the fence

Musolino’s (1998) observation is that children, unlike adults, display a marked tendency to assign sentences like (1), interpretation (1a). This is what Musolino

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grammatical account of OI. Section 3 traces the evolution of OI and chronicles the demise of the grammatical view, Sect. 3.1, and the rise of the garden-path, and QAR approaches to OI, Sects. 3.2 and 3.3 respectively. In Sect. 4, I provide a critical assessment of the QAR approach to OI, and in Sect. 5, I show that Isomorphism is best and most productively understood as a research program, illustrating some of its implications for broader issues of concern to linguists, psycholinguists, and developmental psychologists.

2 Navigating Negative Quantificational Space

This section introduces the phenomenon of quantifier-negation interaction, Sect. 2.1, as well as the developmental effect, based on this phenomenon, that will serve as our prism, namely Musolino’s (1998) Observation of Isomorphism (OI), Sect. 2.2. Section 2.3 reviews the grammatical account of OI originally proposed by Musolino (1998) and Musolino et al. (2000).

2.1 Quantifier-Negation Interaction

To begin, let us consider the linguistic phenomenon that led to Musolino (1998) to uncover OI, namely the interaction of quantified NPs (QNPs) (e.g., every horse, some boys) and negation. As a first step, let us begin by introducing the notion of scope—a key theoretical concept—by using a simple mathematical analogy. Consider the expressions in (2) and (3):

(2) \[ 2 \times (3 + 5) = 16 \]
(3) \[ (2 \times 3) + 5 = 11 \]

The scope of 2x (the number 2 followed by the multiplication sign) can be thought of as its domain of application. So in (2), \((3 + 5)\) falls within the scope of 2x. By contrast, in (3), \((2 \times 3)\) falls within the scope of 2x whereas 5 falls outside of its scope. Finally, notice that different scope relations give rise to different results once the expressions are computed.

We can now turn to the concept of scope as it applies to language by considering the examples in (4) which all contain a QNP and negation.

(4) a. Every horse didn’t jump over the fence.
   b. The Smurf didn’t buy every orange.
   c. Donald didn’t find two guys.
   d. Some girls won’t ride on the merry-go-round.
   e. The detective didn’t find some guys.

First, notice that (4a) is ambiguous. On one reading, it can be paraphrased as meaning that every horse is such that it did not jump over the fence. In other words,
none of them did. In this case, the QNP every horse is interpreted outside the scope of negation (abbreviated not\(\Rightarrow\)not). Following Musolino (1998) and Musolino et al. (2000), I will call this an isomorphic interpretation because in this case semantic scope (i.e., the way the QNP and negation are interpreted with respect to each other) can be directly read off the surface syntactic position (defined in terms of overt c-command relations) between the quantificational elements involved. Alternatively, (4a) can be paraphrased as meaning that not every horse jumped over the fence; i.e. some did but others didn’t. Here, the every horse is interpreted within the scope of negation (abbreviated not\(\Rightarrow\)every). I will call this a non-isomorphic interpretation because in this case, semantic scope does not coincide with the overt syntactic position of the QNP and negation.\(^2\)

Notice that not every sentence containing negation and a universally quantified NP gives rise to the kind of ambiguity just described. To be sure, (4b), which finds the QNP in object position allows only a reading where every orange is interpreted within the scope of negation (not\(\Rightarrow\)every), an isomorphic interpretation. However, replace the universally quantified object in (4b) with a numerically quantified one, as in (4c), and the ambiguity is restored. Indeed, (4c) can either be paraphrased as meaning that it is not the case that Donald found two guys (not\(\Rightarrow\)two), an isomorphic interpretation, or, alternatively, that there are two specific guys that Donald didn’t find (two\(\Rightarrow\)not), a non-isomorphic interpretation.

Returning to example (4a), we can now see that the availability of a non-isomorphic interpretation is a function of the lexical nature of the subject QNP. That is, while (4a), which contains a universally quantified NP, is clearly ambiguous, (4d), which contains an existentially quantified subject, is not. The most natural interpretation of (4d) is one on which it can be paraphrased as meaning that there are some girls who didn’t ride on the merry-go-round (some\(\Rightarrow\)not), an isomorphic interpretation. Finally, the fact that QNPs like some N and every N give rise to different interpreters when they occur as the subject of a negative statement also holds when they occur in object position. To witness, recall that (4b), which contains a universally quantified object, must receive an isomorphic interpretation. By contrast, (4e), where the QNP some N occurs in object position, must receive a non-isomorphic interpretation. In other words, (4e) can only be paraphrased as meaning that there are some guys that the detective didn’t find (some\(\Rightarrow\)not), a non-isomorphic interpretation, and not as meaning that the detective didn’t find anybody (not\(\Rightarrow\)some), an isomorphic interpretation.

Let us take stock. We have seen that sentences containing QNPs and negation give rise to isomorphic and non-isomorphic interpretations. Moreover, non-isomorphic interpretations are sometimes obligatory, sometimes optional, and sometimes unavailable. Finally, the availability of such interpretations depends on at least two factors: the lexical nature of the QNPs involved as well as their syntactic position. Given the complex mapping between form and meaning at play here, it is natural for someone interested in the acquisition of semantics to wonder how children manage to navigate this interpretive maze and arrive at the correct generalizations regarding the facts described above.

### 2.2 The Observation of Isomorphism

The considerations discussed above led Musolino (1998) to systematically assess the way preschoolers and adult speakers of English interpret sentences containing QNPs and negation in a series of psycholinguistic experiments using the Truth Value Judgment Task methodology (TVJT). The logic of the experimental approach developed by Musolino (1998) was to create situations that could be described using the sentences in (4) and in which each target sentence was true on one reading and false on the other. Participants’ acceptance/rejection of the target sentences, along with appropriate justifications, was then taken as a measure of which reading they were accessing (isomorphic or non-isomorphic). To make things more concrete, let us consider a typical scenario used to test participants’ interpretation of sentences (4a, b). Beginning with the former, imagine a situation in which three horses decide to practice jumping over various obstacles, and two of those horses end up jumping over a fence (picture 1). A puppet then describes the situation by saying: “Every horse didn’t jump over the fence, am I right?”. If one were to interpret the puppet’s statement as meaning that none of the horses jumped over the fence (every\(\Rightarrow\)not), an isomorphic reading, then one ought to reject that statement on the grounds that two of the horses did jump over the fence. On the other hand, if the target sentence is interpreted to mean that not all of the horses jumped over the fence (not\(\Rightarrow\)every), a non-isomorphic reading, then one ought to accept it because it is indeed true that not every horse jumped over the fence; two did but one didn’t.

The logic of the stories used to assess participants’ interpretation of sentences containing a universally quantified NP in object position is the same. Consider for example a situation in which a Smurf decides to go to the grocery store to buy some fruit. There he sees some apples and oranges, and he decides to buy one of the three oranges (picture 2). The puppet then describes the situation by saying: “The Smurf didn’t buy every orange, am I right?” As before, interpreting the target sentence to mean that the Smurf bought none of the oranges (every\(\Rightarrow\)not), a non-isomorphic interpretation in this case, should lead to rejection of the puppet’s statement because the Smurf did buy one of the oranges. By contrast, interpreting the target sentence to mean that not all of the oranges were bought by the Smurf (not\(\Rightarrow\)every), an isomorphic reading, should lead one to accept the puppet’s statement because the Smurf bought one of the three oranges, but not the other two.

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\(^2\)It has been suggested to me that whether negation appears in contracted or uncontracted form may affect the ambiguity pattern (Norbert Hornstein, p.c. for cases like Every horse didn’t jump over the fence, and Tom Roeppe, p.c., for cases like The Smurf didn’t buy every orange). However, I am not aware of any experimental evidence bearing on this issue.
When tested under the conditions described above, both preschoolers and adults easily accessed the isomorphic interpretation of sentences like *Every horse didn’t jump over the fence* (i.e., not > every), and both groups correctly explain that the puppet is right because the Smurf only bought one of the three oranges. More surprising is children’s responses to sentences like *Every horse didn’t jump over the fence*. Here, adult participants almost always accept the puppet’s statements on the grounds that only two of the three horses made it over the fence (see picture 1), clearly accessing the isomorphic interpretation of the target sentence (not > every). By contrast, preschoolers in the same situation systematically reject the puppet’s statement, because, as the children explained, two horses did jump over the fence. Thus, whereas adults can easily access the non-isomorphic interpretation of sentences like *Every horse didn’t jump over the fence*, preschoolers systematically access the isomorphic interpretation.

In fact, the pattern just described generalizes to all the cases of quantifier-negation interaction described in (4). This is what Musolino (1998) called the Observation of Isomorphism (OI) (see Table 1). In a nutshell, OI captures the observation that children systematically compute semantic scope on the basis of overt syntactic scope. Musolino et al. (2000), following Musolino (1998), define OI as follows:

**The observation of Isomorphism**

Unlike adults, young children systematically interpret negation and quantified NPs on the basis of their position in overt syntax.

Since Musolino (1998), OI has been replicated by different investigators, in languages such as English (Musolino and Lidz 2006; Conroy 2008; Gualmini 2004; Conroy et al. 2009), French (Noveck et al. 2007), Kannada (Lidz and Musolino 2002, 2005/2006), and Korean (Han et al. 2007).

### Table 1: The Observation of Isomorphism

<table>
<thead>
<tr>
<th>Sentence Type</th>
<th>Children</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Every horse didn’t jump over the fence</em></td>
<td>not &gt; not</td>
<td>not &gt; every</td>
</tr>
<tr>
<td><em>The Smurf didn’t buy every orange</em></td>
<td>not &gt; every</td>
<td>not &gt; every</td>
</tr>
<tr>
<td><em>Some horses won’t jump over the fence</em></td>
<td>not &gt; some</td>
<td>some &gt; not</td>
</tr>
<tr>
<td><em>The detective didn’t find any guys</em></td>
<td>not &gt; some</td>
<td>some &gt; not</td>
</tr>
<tr>
<td>Cookie Monster didn’t eat two slices of pizza</td>
<td>not &gt; two</td>
<td>not &gt; two</td>
</tr>
</tbody>
</table>

### 2.3 Isomorphism as a Grammatical Epiphenomenon

The Observation of Isomorphism, and, more generally, the existence of any systematic difference in the linguistic behavior of children and adults, raise a number of questions that we will discuss throughout this chapter. Among them is the question of what causes children to behave isomorphically in the first place. Musolino (1998) offered an account of the causal question based on the idea that preschoolers and adults have different grammars when it comes to the phenomenon under consideration. Specifically, Musolino proposed that preschoolers find themselves at a developmental stage where their computational system cannot yet generate linguistic representations that correspond to non-isomorphic interpretations, hence their necessarily isomorphic behavior.

Importantly however, Musolino (1998) regarded isomorphism as an *epiphenomenon*; an emerging property arising from the interaction of deeper linguistic principles. The linguistic principles in question are the subset condition (Berwick 1985; Waxler and Manzini 1987; Crain and Thornton 1998) and the typology of QNPs. The basic idea regarding QNPs is that they come in two flavors. The first kind, Type 1 QNPs, rely on a single mechanism for purposes of scope-taking, grammatical movement (i.e., A-movement in Hornstein’s 1995 system), and they are always interpreted isomorphically with respect to negation. So for example, an object QNP of Type 1 will always be interpreted within the scope of negation because AgrO, the position to which it would move, is hierarchically lower than NegP. Thus, the object QP will always occur within the c-command domain of negation, and it will therefore be interpreted within its scope. By contrast, the second kind, Type II QNPs, have an additional, non-movement-based mechanism at their disposal (Hornstein 1984, 1995; Reinhart 1995, 1997). What this means is that Type II QNPs can

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1The following quote from Musolino (1998) illustrates this important point: “There would be a simple way to capture the observation of isomorphism: take isomorphism at face value and invoke it as a primitive learning principle. Call it ‘the Principle of Isomorphism’. My purpose in this section is to argue that this is not the right way to proceed however... My contention, therefore, is that isomorphism in the acquisition of QNP-Neg interaction is *epiphenomenal* [my emphasis]. It should be regarded as an *emergent property* [my emphasis] arising from the interplay between properties of QNPs and learnability considerations.” (p. 149)
be interpreted in positions that are different from their surface syntactic position—i.e., non-isomorphically—by a mechanism that does not yield the typical signature of syntactic movement (e.g., locality effects). For example, in Reinhart’s (1995) system, Type II QNPs can be interpreted as choice functions. Thus, Type I QNPs have a subset of the options available to Type II QNPs, thereby creating the familiar subset/superset configuration required for the operation of the subset principle which, on this account, would then compel children to initially hypothesize that all QNPs are of type 1. And since Type I QNPs never give rise to non-isomorphic interpretations, children’s isomorphic behavior follows straightforwardly.

In fact, the account outlined above works for all the cases in (1), expect for sentences like Every horse didn’t jump over the fence. Here, the key observation is that while such sentences are ambiguous in English, and give rise to an isomorphic and a non-isomorphic interpretation, they are unambiguous in Chinese, and only give rise to an isomorphic interpretation (every>not). Following the logic discussed above, Musolino hypothesized that English-speaking preschoolers go through a Chinese-speaking phase during which they initially treat such sentences as unambiguous and assign them only an isomorphic interpretation.

3 Shades of Isomorphism: Grammar, Parsing and Pragmatics

In this section, I review developments that followed the formulation of OI and the grammatical account introduced above. I first show, in Sect. 3.1, that there are now good reasons to believe that the grammatical account should be abandoned. In Sect. 3.2, I turn to an alternative account of the facts uncovered by Musolino (1998) known as the garden-path account (Musolino and Lidz 2003/2006). Finally, in Sect. 3.3, I introduce a competing account of OI proposed by Gualmini and colleagues (Gualmini et al. 2008), called the Question-Answer-Requirement (QAR).

3.1 Against the Grammatical View of Isomorphism

As work on Isomorphism progressed beyond the original studies described in the previous section, and new results began to appear, it soon became apparent that Musolino’s (1998) grammatical account could not be maintained. Two mutually reinforcing sets of findings lead to this conclusion. The first is that under certain experimental conditions, children can be shown to access non-isomorphic interpretations at or near adult-like levels. The second is that the isomorphism effect can be induced in adults, who undoubtedly have mature grammars.

Beginning with adults, Musolino and Lidz (2003) showed that the isomorphism effect seen in children in the case of sentences like (5) (Musolino 1998; Lidz and Musolino 2002) could also be observed in mature speakers in the case of sentences like:

(5) Cookie Monster didn’t eat two slices of pizza.
(6) Two frogs didn’t jump over the rock.

In both cases, participants were tested in two conditions: an Isomorphic condition, in which the isomorphic readings of the sentences are true and the non-isomorphic readings are false, and a Non-isomorphic condition in which the isomorphic readings are false and the non-isomorphic readings are true. These design features are implemented in the same way for both sentence types. In the Isomorphic condition, the action described by the verb was performed only with respect to one of two objects (or performed by only one of two characters) whereas in the Non-isomorphic condition, the total number of objects is four instead of two, and the action is performed with respect to only two of them (or performed by only two out of four characters).

So for example, in the isomorphic condition corresponding to (5), Cookie Monster ate only one of two slices of pizza which makes the isomorphic reading (not>two) true since it is indeed not the case that Cookie Monster ate two slices of pizza, and the non-isomorphic reading (two>not) false since it is not true that there are two slices of pizza that Cookie Monster didn’t eat. In the non-isomorphic condition, Cookie Monster eats two out of four slices of pizza which makes the isomorphic reading (not>two) false, since Cookie Monster ate exactly two slices of pizza, and the non-isomorphic reading (two>not) true, since there are indeed two slices of pizza that Cookie Monster didn’t eat.

Under those conditions, Lidz and Musolino (2002) showed that adult speakers of English accept the puppet statements equally often in the Isomorphic and Non-isomorphic condition corresponding to sentences like (5) (97% and 93% acceptance rate, respectively), demonstrating that they can easily access both interpretations. Children, however, display a strong preference for the Isomorphic interpretation, manifested by a significantly lower acceptance rate in the non-isomorphic condition (where the non-isomorphic reading is true) compared to the isomorphic condition (where the isomorphic reading is true) (33% vs. 81% acceptance rate, respectively). When asked to justify their negative answers in the non-isomorphic condition, children explain that the puppet is wrong by invoking the fact that the isomorphic reading is false.

Musolino and Lidz (2003) showed that the isomorphic pattern observed in preschoolers in the case of sentences like (5) can be induced in adults when they are asked to interpret sentences like (6). Following the experimental logic outlined above, adult speakers of English were tested in two conditions. In the Isomorphic condition, four frogs tried jumping over a rock, and only two succeeded, thus making the isomorphic reading (two>not) true, since there are indeed two frogs that failed to jump over the rock, and the non-isomorphic reading (not>two) false, since there are exactly two frogs that jumped over the rock. In the non-isomorphic condition, which involved only two frogs and where one managed to jump over the rock but the other didn’t, the truth values of the two readings are reversed. This time, the isomorphic reading (two>not) is false, because only one frog — and not
two — failed to jump over the rock, and the non-isomorphic reading (not > two) is true because it is indeed the case that the number of frogs that managed to jump over the rock is not two (since only one frog managed to do so).

What Musolino and Lidz (2003) found here is that adults always accepted the puppet’s statements in the isomorphic condition, thereby easily accessing the isomorphic interpretation of sentences like (6), but that they overwhelmingly rejected the same sentences in the non-isomorphic condition. When asked to explain their negative answers in the non-isomorphic condition, adults explained that the puppet was wrong because the isomorphic interpretation of the sentences was false. In sum, adults failed to access the non-isomorphic interpretations — which were true in this case — and instead accessed the isomorphic readings — where were false in this case. Thus, the Isomorphism effect, originally reported to manifest itself in the behavior of preschoolers, can also be induced in mature speakers of English. This general approach — ‘turning adults into children’ — has also been documented by Conroy (2008) in the case of sentences like Every horse didn’t jump over the fence.

The second line of evidence bearing on the grammatical account comes from studies which show the opposite effect, namely that under certain experimental conditions, children can be shown to behave in a more adult-like fashion. In this regard, Musolino (2000) and then Musolino and Lidz (2006)4 reported that certain contextual manipulations lead to a significant reduction in isomorphic behavior on the part of children. Specifically, Musolino showed that preschoolers systematically accessed the isomorphic interpretation of (7a) (every > not), replicating the original finding, but that they were significantly more likely to access the non-isomorphic interpretation of sentences like (7b) (not > every), which were used to describe a situation in which three horses initially all jumped over a log, and only two of them subsequently made it over a fence.

(7) a. Every horse didn’t jump over the fence
b. Every horse jumped over the log, but/and every horse didn’t jump over the fence.

In a similar vein, Gualmini (2004) manipulated the felicity of the contexts in which negative sentences were used. The key insight exploited by Gualmini is that in order for negation to be used felicitously, it must point to a discrepancy between an expected outcome and the actual outcome of a situation (Wason 1972); a requirement that young children have been shown to be sensitive to (de Villiers and Helen 1975). So for example, Gualmini used sentences like (8a, b) to describe a situation in which a Troll was expected to deliver four pizzas, but because he lost two on his way, only managed to deliver the remaining two.

(8) a. The Troll didn’t deliver some pizzas.
   b. The Troll didn’t lose some pizzas.

In this case, both sentences are false on an isomorphic interpretation (not > some), because it is not true that the Troll delivered or lost none of the pizzas: the two that were lost were obviously not delivered, and the two that were delivered were not lost. On the other hand, the sentences are true on a non-isomorphic interpretation (some > not) because there are indeed some pizzas that were not delivered — the two that were lost — or lost — the two that were delivered. Thus, (8a, b) only differ in how felicitous they are in Gualmini’s pizza story. (8a) is felicitous because the Troll was expected to deliver the pizzas, but (8b) is not, because the Troll’s task was not to lose the pizzas. What Gualmini found here is that preschoolers were much more likely to accept the non-isomorphic interpretation of the felicitous examples, (8a), than the infelicitous ones, (8b).

In sum, the contextual manipulations described above in the Musolino (2000), Musolino and Lidz (2006) and Gualmini (2004) studies led children to behave in a more adult-like fashion in their ability to access non-isomorphic interpretations, a fact which is hard to reconcile with Musolino’s (1998) grammatical account of Isomorphism. Taken together, the evidence that adults can be turned into children, and that children can be turned into adults cast serious doubt on the validity of Musolino’s (1998) grammatical account of Isomorphism, and it is now generally agreed that the answer to what I called the causal question lies elsewhere.

### 3.2 Isomorphism as a Garden-Path Effect

The developments reviewed in the previous section entail that we should shift the focus of our inquiry from the study of grammatical development to the study of ambiguity resolution. Indeed, if preschoolers, like adults, have grammars that allow them to generate both isomorphic and non-isomorphic interpretations, then the key question is now to try to understand why these two populations differ in the way they resolve quantifier-negation ambiguities. In light of the demise of the grammatical account, OI can now be recast as the observation that preschoolers, unlike adults, have a tendency to resolve quantifier-negation ambiguities isomorphically. Why should this be?

One idea, inspired by research in the field of sentence processing, is that the resolution of quantifier-negation ambiguities involves an initial commitment to surface scope which is much more difficult for children to revise away from than it is for adults (e.g., Musolino and Lidz 2003, 2006); a sort of Kindergarten-path effect, to borrow Trueswell et al.’s (1999) catchy phrasing. Notice that this approach relies on two crucial assumptions: that surface scope has a privileged status in that it tends to be initially favored by the parser, and that preschoolers are not yet as efficient as

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4Musolino (2000) was in fact the first to report that certain contextual manipulations can lead to a significant reduction of the isomorphism effect, and to therefore conclude that the grammatical account of Musolino (1998) had to be abandoned. The results presented by Musolino (2000) were later published as Musolino and Lidz (2006).
adults when it comes to revising initial parsing commitments. A review of the literature indicates that there is good evidence supporting both of these assumptions.

Regarding the special status of surface scope, the evidence available points to the conclusion that isomorphic interpretations of sentences containing multiple quantified expressions are theoretically, psychologically, and statistically privileged. To begin, current theoretical models of quantificational interactions view scope-shift—the operation that yields non-isomorphic interpretations—as a computationally costly operation (e.g., Fox 2000; Reinhart 2006). Moreover, Reinhart (2006) argues that this cost has measurable psychological consequences when it comes to the interpretation of quantified sentences.

This conclusion is supported by numerous psycholinguistic studies on this topic, using both off-line and online measures (e.g., VanLehn 1978; Gillen 1991; Kurtzman and MacDonald 1993; Pica and Snyder 1995; Tunstall 1998; Anderson 2004). For example, Tunstall’s (1998) Principle of Scope Interpretation (PSI) is based on the notion that default relative scoping is determined by surface c-command relations, and her condition on general processing economy isomorphism between surface syntactic scope and semantic scope as a default condition to be departed from at cost and only when such departure is motivated by other factors. Anderson (2004) arrives at the same conclusions, and recasts Fox’s (2000) grammatical principle of scope economy as a parsing principle according to which inverse-scope configurations are dispreferred because they are computationally more costly than surface scope interpretations.

Finally, isomorphic interpretations are also privileged in the sense that they seem to be statistically much more frequent than non-isomorphic ones. This bias was documented in a corpus analysis that examined children and adults’ patterns of use of sentences containing quantified NPs and negation performed by Gemari and MacDonald (2005/2006). Since the parser is sensitive to such distributional cues in making initial commitments to a given interpretation in the course of language comprehension, these statistical patterns give us one more reason to believe that isomorphic interpretations will be favored by the parser early on.

The second assumption made by the kindergarten-path approach is that preschoolers are not as efficient at revising initial parsing commitments as mature speakers. This conclusion, as in the previous case, is also supported by independent evidence. In a landmark study, Trueswell et al. (1999) showed that preschoolers demonstrated little to no ability to revise initial parsing commitments involved in sentences containing temporarily ambiguous prepositional phrases (e.g., Put the frog on the napkin in the box). Summarizing what we have learned about the way preschoolers process language in real time over the last decade, Snedeker (2009) arrives at the same conclusion.

Thus, the kindergarten path approach to children’s isomorphic behavior is compatible with what we know about how quantifier scope ambiguities are resolved, as well as how children process language in real time. Importantly, on this view, the kind of preference for surface scope that we have been discussing is one of many interacting factors that contribute to the interpretation of a sentence. Moreover, such a preference only represents a probabilistic tendency, which means that its effects can be mitigated—if not outright eliminated—by other, interacting factors. For example, one of the many factors that is known for its role in alleviating garden-path effects is contextual information (e.g., Crain and Steedman 1985; Altman and Steedman 1988; Tanenhaus et al. 1995, among many others). On this view, it is not surprising to find that when certain contextual features are manipulated, as in the studies by Musolino (2000), Musolino and Lidz (2006), and Gualmini (2004) discussed in the previous section, children’s isomorphic behavior is significantly reduced.

On the original account proposed by Musolino (1998) and Musolino et al. (2000), OI was treated as a descriptive generalization, and the notion of Isomorphism itself was regarded as an epiphenomenon: an emerging property arising from the interaction of deeper grammatical principles. An interesting consequence of the demise of the grammatical view is that the notion of isomorphism, once regarded as a mere artifact, now lies at the heart of the garden-path approach. To be perfectly clear though, this does not mean that there is an ‘isomorphic principle’ which predicts that the interpretation selected by children will always be the isomorphic one. Rather, in accordance with much recent work on language processing, isomorphism qua the tendency to rely on surface scope—is regarded as one of the multiple factors that conspire to determine a final interpretation, which may of course ultimately differ from the isomorphic one.

3.3 Isomorphism as a Pragmatic Epiphenomenon

Building on the work of Gualmini (2004) discussed in the previous section, Gualmini and colleagues (Gualmini 2008; Gualmini et al. 2008) developed a radically different account of children’s non-adult preferences which views OI as a pragmatic epiphenomenon. On this view, called the Question-Answer Requirement (QAR), the ‘illusion of isomorphism’ follows from a general pragmatic requirement that dictates which interpretation of an ambiguous sentence children (and adults) select, regardless of the syntactic structure of that sentence. Specifically, QAR rests on the assumption that a sentence is always understood as an answer to a question. The interpretation that children (and adults) select, in turn, must be a good answer to a Question under Discussion (QUD) (i.e., the salient question available in the context of a TVJIT). An answer qualifies as a ‘good answer’ to a Yes/No question if it entails either the Yes or the No answer to that question. Finally, when both readings of an ambiguous sentence constitute good answers to the QUD, children (and adults) select a reading on the basis of the Principle of Charity according to which they will give a ‘yes’ answer whenever this is possible.

To illustrate the operation of QAR, let us return to Gualmini’s (2004) ‘pizza story’ discussed in the previous section. Recall that in that story, a Troll has to deliver four pizzas, but he ends up losing two of them. In the end therefore, the Troll delivers only two pizzas. Consider (9) and (10) as descriptions of what happened in the pizza story. Recall that both sentences are false on an isomorphic interpretation (not > some), because it is not true that the Troll delivered or lost none of the pizzas: the two that were lost were obviously not delivered, and the two that were delivered were not lost. On the other hand, the sentences are both true on a non-isomorphic interpretation (some > not) because there are indeed some pizzas that were not delivered—the two that were lost—or lost—the two that were delivered.
The Troll didn’t deliver some pizzas.
(a) It is not the case that the Troll delivered some pizzas = the Troll didn’t deliver any pizzas (FALSE)
(b) There are some pizzas that the Troll didn’t deliver (TRUE)

The Troll didn’t lose some pizzas
(a) It is not the case that the Troll lost some pizzas = The Troll didn’t lose any pizzas (FALSE)
(b) There are some pizzas that the Troll didn’t lose (TRUE)

Since it is made clear in the context of the story that the Troll has to deliver all the pizzas, Gualmini et al. (2008) take (11) to be the relevant QUD.

Will the Troll deliver all the pizzas?

To illustrate the mechanics of the QAR, consider the target sentence in (9) uttered as a description of the pizza story. In this case, both readings of (9) are good answers to the QUD in (11). To see why, notice that (9a), which can be paraphrased as meaning that the Troll didn’t deliver any of the pizzas, clearly entails a negative answer to the question of whether the Troll has delivered all the pizzas. Similarly, (9b), which can be paraphrased as meaning that there are some pizzas that were not delivered, also entails a negative answer to the QUD in (11). In this case, since both interpretations of the target sentence constitute good answers to the QUD, the final arbiter is the principle of charity which compels children to select the interpretation that is true in the context under consideration, namely the non-isomorphic interpretation in (9b).

Thus, the QAR predicts that children will interpret (9) non-isomorphically, as is indeed the case in the study conducted by Gualmini (2004).

Let us now turn to the example in (10). According to Gualmini et al. (2008), the wide scope reading of (10), (7b), does not constitute a good answer to (11) because the fact that there are some pizzas that the Troll didn’t lose (which is equivalent to saying that there are some pizzas that the troll delivered) does not entail that the Troll either delivered or failed to deliver all the pizzas. On the other hand, the narrow scope reading of (10), (10a), does constitute a good answer to (11) since saying that the Troll didn’t lose any of the pizzas is equivalent to saying that he delivered them all. Thus, the QAR correctly predicts that children should display a preference for the narrow scope interpretation of (10), (10a), since only it constitutes a good answer to the QUD in (11).

At this point, it is important to observe that the narrow scope reading of (10) also happens to be the isomorphic interpretation of (10). The pivotal difference between the garden-path approach to isomorphism and the QAR should now be clear: whereas isomorphism takes children’s scope preferences to be a direct consequence of the surface syntactic position of the quantificational elements involved, QAR does not assign any privileged status to surface c-command relations – or syntactic structure more generally – and thus treats isomorphism as an epiphenomenon.

In order to test the predictions of QAR, and compare the results to the set of sentences tested by Musolino (1998), Gualmini et al. (2008) investigated children’s (and adults’) interpretation of sentences like (12–14).

(12) a. Some pizzas were not delivered.
    b. Some pizzas were not lost.

(13) The Troll didn’t deliver two pizzas.

(14) Every letter wasn’t delivered.

For sentences like (12), these authors report the same pattern of results as the ones where the QNP occurs in object position, i.e. (9–10). That is, children overwhelmingly accept sentences like (12a) on the reading where some takes wide scope over negation, whereas in the case of sentences like (12b), children accept the same reading much less often. In other words, the same pattern of results obtains whether the QNPs occur in subject or object position, not what one would expect on the garden-path theory of isomorphism according to Gualmini et al. (2008). Finally, these authors report that in the experiments they ran to assess children’s interpretation of sentences like (13–14), using stories modeled after Gualmini’s (2004) pizza story, preschoolers overwhelmingly accepted the target sentences on their non-isomorphic interpretations, unlike what had been previously reported in the literature (e.g., Musolino 1998; Lidz and Musolino 2002; Musolino and Lidz 2006).³

In addition to offering a new account of children’s interpretation of quantifier-negation ambiguities, Gualmini (2008) makes two important, additional claims. The first is that we should abandon the notion of isomorphism altogether, be it a descriptive generalization, as in Musolino (1998), or one of the factors contributing to children’s behavior, as in Musolino and Lidz (2003, 2006), and, consequently, that broader conclusions based on the notion of Isomorphism have to be reconsidered. The following two quotes from Gualmini (2008) illustrate these points:

We argue that the observation of Isomorphism has no place in our theory of child language. In particular, we highlight the theoretical and empirical shortcomings of current theories which attribute a privileged role to surface scope in children’s parsing (e.g., Musolino and Lidz 2006). Furthermore, we show that the Observation of Isomorphism cannot even be invoked to describe children’s non-adult behavior … (p. 1158)

Having argued that there is no reason to assume that surface scope interpretations have a privileged status in children’s grammar, it is important to consider what consequences can be drawn. This amounts to re-examining the consequences that have been drawn on the basis of the incorrect hypothesis that children display a preference for surface scope interpretations. In particular, we consider how Isomorphism has been brought to bear on experimental methodology, the role of the input for language acquisition, learnability and the time-course of parsing. (p. 1172)

³In the next section, I discuss possible reasons for this discrepancy.
The spirit of this approach is aptly captured by the title of Gualmini’s (2008) article, ‘The rise and fall of Isomorphism’. In the next section, I turn to an evaluation of the QAR.

4 Assessing the QAR

We all agree that the context in which ambiguous sentences are presented plays an important role in determining which interpretation children (and adults) eventually select. Thus, in trying to formalize the role played by contextual factors, Gualmini and colleagues are definitely on to something important. Another desirable feature of the QAR – which is an improvement over the garden-path approach – is that Gualmini’s model actually makes predictions regarding when one should expect children to behave isomorphically and when one should not. Finally, the QAR forces us to look at old puzzles in new ways. For example, work by Krämer (2000) revealed a pattern in Dutch-speaking children which is the opposite of the one originally described by Musolino (1998). That is, children, unlike adults, were found to behave non-isomorphically in their interpretation of sentences containing indefinite QNPs and negation. As pointed out by Gualmini, the QAR approach offers a new way to make sense of this apparently contradictory set of results (Unsworth and Gualmini 2008). Based on the ideas developed in the QAR approach, these authors propose that the behavior of Dutch and English-speaking children, while superficially paradoxical, can in fact be explained in the same way: in both cases, children select the interpretation that answers the relevant QUDs. Let me now turn to Gualmini’s three claims, namely (a) that the QAR is all we need to explain the relevant set of facts, (b) that there is no place in our theory of child language for the notion of isomorphism, and (c) that the consequences that have been drawn on the basis of OI must be reconsidered. Let us begin with (b). Here, it is now clear that OI cannot be invoked as a descriptive generalization of the relevant set of facts, for the obvious reason that we have learned since Musolino (1998) that children do not always behave isomorphically when it comes to interpreting sentences containing quantified NPs and negation. The best we can say now is that children sometimes behave isomorphically.

However, the QAR approach takes this conclusion one step further in claiming that reliance on surface scope should not even be considered as one of the factors involved in the comprehension process, regardless of which interpretation is ultimately selected. To quote Gualmini:

Given that children can access either interpretation of a scopally ambiguous sentence, assuming that children have little or no ability to revise their initial commitment, the reasonable conclusion to draw is that inverse scope may be the first interpretation entertained by children’s parsers. As far as the interpretive component of the parser is concerned there is no reason to assume that surface scope interpretations have a privileged status. (p. 1174)

However, what is known about this topic points to a different conclusion regarding the status of surface scope. Indeed, recall from our previous discussion that surface scope interpretations are theoretically, psychologically, and statistically privileged. So there are indeed good reasons to believe that surface scope interpretations are

and Conroy 2008 for a review of the relevant facts as well as new experimental evidence). Moreover, one of Anderson’s (2004) conclusions is that the cost associated with the computation of inverse scope is also measurable in contexts that support the inverse scope interpretation, and, more strikingly, even when the sentence is unambiguous and only allows an inverse scope reading.

Now of course, quantifier-negation ambiguities in child language may be a totally different beast and challenge everything we know about scope ambiguity resolution and parsing. But this should certainly not be the default assumption, and given what is known, the burden of proof would seem to fall on those claiming that we should take a radical departure from our present state of understanding. Of course, this issue can be settled empirically, for example by collecting online data to determine the incremental signature of the comprehension process in this specific case; a research effort that we are currently undertaking. At any rate, until we know more about how quantifier-negation ambiguities are resolved in real time (by children and adults), we should keep an open mind about the potential factors involved.

Let us now consider (a), namely the claim that the QAR is all we need to account for the relevant set of facts. In this regard, Gualmini (2008) concludes that “despite the concerns raised by Musolino and Lidz (2003), the empirical coverage of the QAR theory is remarkable.” However, a closer inspection of the evidence proposed by Gualmini and colleagues reveals that the overall case for the QAR remains to be made. The main reason for this state of affairs lies in the way proponents of the QAR have chosen, at least so far, to test their ideas. Given that the QAR makes very clear predictions, there would be an easy way to proceed: design a controlled set of studies aimed at directly testing the predictions of the QAR. Instead, the authors chose a different path which relies in large part on post-hoc speculation and questionable experimental methodology. Consequently, all we can say for sure is that context matters, a conclusion that all parties to this debate have been in agreement about for a while now. Whether context actually matters in the way the QAR predicts remains an open question. But even if it did, there is now growing evidence that an account like the QAR is only one piece of the isomorphic puzzle.

Let us first consider what would seem to be a straightforward way to test the predictions of the QAR. Recall from our previous discussion (Sect. 3.3) that a key question for the QAR has to do with trying to decide, for any given story, what the relevant Question under Discussion (QUD) should be. Given the mechanics described in Sect. 3.3, this step is crucial. Indeed, recall that the nature of the lexical items contained in the QUD determines the relevant entailment patterns, and thus, which of the two readings of an ambiguous sentence constitutes a ‘good answer’. What this means is that the QAR is exquisitely sensitive to the kind of expressions contained in QUDs, since different verbs, quantifiers, etc. give rise to different entailment patterns.

So to build a strong case, it would be preferable to not have to guess, post-hoc, what the QUD might have been. An easy way to circumvent this problem, as pointed out by Musolino and Lidz (2003), and acknowledged by Gualmini et al. (2008),

4Indeed, Gualmini et al. (2008) remark that “… the particular way in which the story is told is not the only way to make explicit the Question under Discussion. An obvious possibility would be for
would be to make the QUQ explicit, which would allow experimenters to carefully control and manipulate their content. The next step would be to test children in different conditions, including a baseline condition, so as to show that manipulating stories/QUQs according to the predictions of the QAR indeed has the desired effects. The baseline condition could be one of the stories used by Musolino (1998) to document the Isomorphic effect in the first place. Critical conditions would contain explicit QUQs predicted to lead children to behave isomorphically or non-isomorphically. And of course, this should be systematically done for various constructions tested by Musolino (1998). To the extent that children were found behave according to the predictions of the QAR under those conditions, one would have solid evidence supporting the account proposed by Gualmini and colleagues.

However, this is not how proponents of the QAR proceeded. In their main published study on this topic, Gualmini et al. (2008) present three experiments designed to test the predictions of the QAR by assessing the way children and adults interpret the sentences in (15–16). In those experiments, however, the QUQs are never made explicit and are always reconstructed post-hoc, baseline conditions are not used, critical factors such as age of the child participants and target materials are not controlled for, and in spite of these serious problems and confounds, Gualmini et al. (2008) reach their conclusion by comparing results across studies conducted by different authors.

(15) a. The Troll didn’t deliver two pizzas.
b. Every letter wasn’t delivered.

(16) a. Some pizzas were not delivered
b. Some pizzas were not lost.

For example, these authors presented children with sentences like Every letter wasn’t delivered in the context of a story in which the main character delivered only three of the four letters he was supposed to deliver. In the end, therefore, the isomorphic reading (every > not) is false, because three letters were delivered, and the non-isomorphic reading (not > every) is true, because not all the letters were delivered. In this case, the QAR predicts, according to Gualmini et al. (2008), that children should select the non-isomorphic interpretation (not > every), and these authors report that the preschoolers they tested did 80% of the time; a rate that is much higher than the one reported in previous studies (e.g., Musolino 1998; Musolino and Lidz 2006). These results, the authors conclude, provide evidence for the QAR.

What is there to complain about? If the devil is in the details, this is precisely what is wrong here. So let’s take a closer look at the details. The first problem is that the authors only guessed, post-hoc, what the relevant QUQ was, which allows them to select precisely what they needed for the account to go through. We’ll see when we consider their next experiment how much of a problem this is. The second problem is that the age of the children that Gualmini et al. (2008) tested is very different from that of the children tested in the other two studies that these authors compare their results to in order to make their claim, namely Musolino (1998) and Musolino and Lidz (2006). Indeed, the children tested by Gualmini et al. were between the ages of 3;0 and 5;11 (mean age = 4;8) whereas the children tested by Musolino (1998) and Musolino and Lidz (2006) were between the ages of 4;0 and 7;3 (mean age = 5;11), and 5;0 and 5;11 (mean age = 5;4), respectively. So the children tested by Gualmini et al. were on average about a year younger than the ones tested in previous studies and the range differed by up to two years. Such differences are crucial in light of results reported by Conroy et al. (2009) who show that while 5-year-olds tested on sentences like Every N didn’t VP do behave-isomorphically, as reported in previous studies, 4-year-olds do not. Instead, the younger children in Conroy et al. (2009) did not behave differently from adults and were found to accept non-isomorphic interpretations 81% of the time, which is almost identical to the 80% rate of acceptance reported by Gualmini et al. (2008). What this means, of course, is that Gualmini et al.’s results could be due to age and have nothing to do with the QAR.

A third problem is that the materials Gualmini et al. (2008) used in their experiment differ from the ones used in previous studies in that they contain passive sentences instead of active ones (e.g., Every letter wasn’t delivered vs. Every horse didn’t jump over the fence) as well as a different choice of predicates, two factors known to affect comprehension in the psycholinguistic literature, including the literature on scope ambiguity. This brings us to a fourth, related problem, namely the fact that Gualmini et al., in spite of the obvious confounds just mentioned (i.e., different ages and materials), did not report using any baseline or control conditions against which to assess performance in their experimental condition. In the end, therefore, there is simply no way of knowing what caused children’s high acceptance rates, and therefore, such results cannot be taken as evidence supporting the QAR.

Let us now consider Gualmini et al.’s (2008) second experiment, designed to test sentences like The Troll didn’t deliver two pizzas (12a). Here these authors conjecture, post-hoc, that the relevant QUQ is Did the Troll deliver all the pizzas, presumably because the Troll’s job was to deliver the pizzas. Given this QUQ, Gualmini and al. point out that only the non-isomorphic reading of (12a), (two > not), represents a ‘good answer’. Indeed, saying that there are two pizzas that the Troll didn’t deliver entails a no answer to the question of whether the Troll delivered all the pizzas. In this case, Gualmini et al. (2008) report that the group of children they tested accepted the target sentences on their non-isomorphic interpretation 75% of the time, again a higher percentage compared to the ones reported in previous studies (e.g., Lidz and Musolino 2002), hence the conclusion that these results provide support for the QAR.

The problem here is that it is not clear at all that children’s elevated acceptance rate is due to the QAR. To see this, consider the study by Lidz and Musolino (2002), designed to test children’s interpretation of sentences like The detective didn’t find two guys. In the relevant condition, such sentences were used in the context of a story where a detective, Donald, and four of his friends play hide-and-seek.

7In the analysis proposed by Conroy, Lidz, and Musolino (2009), this U-shaped developmental trajectory is argued to derive from the development of parsing mechanisms that generate multiple interpretations of an ambiguous sentence as well as processes involved in selecting or revising among these alternatives.
In the end, Donald manages to find two of his friends, but he fails to find the other two. Thus, in this context, the non-isomorphic reading, (two > not) is true, because there are indeed two friends that Donald didn’t find, and the isomorphic reading, (not > two), is false, because Donald found exactly two of his friends. Given that the story was about hide-and-seek, and that Donald was therefore expected to try to find all of his friends, it would make sense, following Gualmini et al.’s (2008) reasoning, to assume that the relevant QUD, like in their pizza story, would be something like *Did Donald find all of his friends?*

The problem should now be clear: the QAR would predict in this case too that children should show a marked preference for the non-isomorphic interpretation of sentences like *The detective didn’t find two guys* for precisely the reasons discussed by Gualmini et al. (2008) in the context of their pizza story. But this is not what happened. Here, children displayed a strong preference for the isomorphic interpretation instead, and only accepted the non-isomorphic interpretation a third of the time. One could argue that if taken at face value, the data reported by Litz and Musolino (2002) falsify the QAR, or at least demonstrate that it is not a sufficient condition on scope interpretation. A proponent of the QAR might reply that perhaps the QUD in Litz and Musolino’s (2002) detective story was different from the one mentioned above. But who’s to decide and on what basis? This highlights a fundamental problem for the QAR as currently tested: in order to assess the predictions of this new model, one cannot go about guessing what the QUDs might have been, in one’s own experiments as well as those of others, when it would be easy to make those questions explicit and remove the need to rely on post-hoc speculation. Finally, Gualmini et al.’s (2008) third experiment designed to test children’s interpretation of sentences containing *some* in subject position, as in (13), suffers from some of the same problems. Their results go in one direction but results reported by Musolino (1998) go in the opposite direction, leading Gualmini et al. to speculate that perhaps the stories used by Musolino didn’t “readily suggest a specific question that could only be addressed by the inverse scope interpretation ...” (p. 226).

In sum, what seems to be clear is that children can access both isomorphic and non-isomorphic interpretations of scopally ambiguous sentences, and that the context in which these sentences are presented matters. For all the reasons discussed above, whether the context matters in the way described by the QAR remains an open question. Moreover, there is now growing evidence that even if the QAR was one of the factors involved in determining which interpretation children ultimately select, it would not be the only factor.

Let me now briefly discuss the results of two studies that point in this direction. The first was conducted by Musolino and Gualmini (2004) who tested children’s interpretation of sentences like (17).

(17) a. The Smurf caught all the cats but she didn’t catch two birds
b. The Smurf didn’t catch two of the birds

These sentences were tested in the same kinds of contexts which should have given rise to the same QUDs. Therefore, children should have accessed the same interpretation in both cases, presumably the non-isomorphic interpretation if we follow Gualmini et al.’s (2008) logic. However, what Musolino and Gualmini (2004) found is that children interpreted (17a) isomorphically, replicating Litz and Musolino’s (2002) results, but that they interpreted (17b) non-isomorphically. This shows that the presence of a partitive construction is enough to push children away from their isomorphic tendencies, a fact that seems to have little to do with felicity, context, or QUDs. What this demonstrates is that the QAR cannot be the only factor at play here, and that lexical factors may be an important part of the isomorphic equation, a conclusion that is hardly surprising in light of what we have learned about sentence processing over the last 20 years.

A similar conclusion was reached by Viau et al. (2010) who investigated the role of priming in the interpretation of scopally ambiguous sentences. Focusing on the case of sentences like *Every horse didn’t jump over the fence*, these authors showed that the non-isomorphic interpretation of such sentences can be primed in ways that are inexplicable on the QAR. In one of their experiments, Viau et al. tested children in two conditions: a baseline condition and a priming condition. In both conditions, context was held constant and sentences were used in stories that have been found to elicit isomorphic responses from children. So by Gualmini et al.’s (2008) standards, those contexts must have given rise to QUDs for which only the isomorphic reading of the target sentences were good answers. In the baseline condition, children heard two blocks of three stories followed by target sentences like *Every horse didn’t jump over the fence*. Not surprisingly, in both blocks, children behave isomorphically. In the priming condition, children also heard two blocks of three stories for which the contexts were identical to the ones in the baseline condition. In the first block, the stories were described by statements like *Not every horse jumped over the fence*, which are unambiguous and must receive a non-isomorphic interpretation. Those were the primes. In the second block, following the primes, children heard sentences like *Every horse didn’t jump over the fence* in contexts found to elicit isomorphic interpretations in the baseline condition. However, children assigned those sentences non-isomorphic interpretations significantly more often compared to the baseline condition, demonstrating that such readings can be primed by structural factors that have nothing to do with context, felicity or the QAR. The fact that non-isomorphic readings can be primed entails that the language processor must be involved (Branigan 2007; Viau et al. 2010), and thus that QAR cannot be the whole story.

5 Isomorphism as a Research Program

Throughout this chapter, the notion of Isomorphism has played a central role in our discussion of the phenomena under consideration. In this section, I would like to take a closer look at this notion and ask: what exactly is Isomorphism? This question, I would like to argue, like the sentences we’ve been dealing with here, can be construed in two ways: narrowly and broadly. When narrowly construed, the question of what Isomorphism is amounts to asking whether isomorphism between syntactic
and semantic structure plays any descriptive or causal role in our understanding of the way children (and adults) interpret scopally ambiguous sentences containing QNPs and negation. By contrast, the broad construal, hitherto not explicitly formulated, is what has been implicitly driving the work of Musolino and colleagues, as well as others, since Musolino’s (1998) original formulation of OI. On this construal, Isomorphism is best understood as a research program. Let me first briefly consider the narrow view, and then turn to the broader interpretation to which the rest of this section is devoted.

I should begin by pointing out that the notion of Isomorphism, as narrowly construed, has undergone a number of transformations since Musolino (1998), and currently represents the main point of contention between the garden-path and the QAR approaches to OI discussed earlier. Recall that the term Isomorphism was initially used by Musolino (1998) as a descriptive label and viewed as a grammatical epiphenomenon. The demise of the grammatical account, in turn, implicitly propelled isomorphism to the front seat where this notion — qua tendency to rely on surface syntactic scope — came to be viewed as one of the causal factors at play in the way children and adults resolve scopally ambiguous sentences containing QNPs and negation (e.g., Musolino and Lidz 2003, 2006). With the advent of the QAR, Isomorphism was demoted to its earlier status of an epiphenomenon, albeit a pragmatic one this time, instead of a grammatical one. Thus, when Gualmini (2008) announced the end of Isomorphism — prematurely as we saw in Sect. 4 — he primarily attacked the narrow view, although he also clearly argued that the consequences of Isomorphism for experimental methodology, learnability, as well as the development of language processing abilities had to be reconsidered as well.

While some of the points offered by Gualmini (2008) are indeed well–taken, as acknowledged in Sect. 4, his general approach fails to consider Isomorphism more broadly and realize that over the last decade the observation described by Musolino (1998) has led to a productive research program. Although research programs are usually discussed in the context of mathematics and the physical sciences (e.g., Hunt 1991), they nevertheless represent an important part of the scientific process for many disciplines, as discussed for example by Boeckx (2006) for linguistics and demonstrated by Pinker’s (1999) words and rules approach. Focusing on the case of the German mathematician David Hilbert and what came to be known as Hilbert’s program, Boeckx explains that “Hilbert proposed a set of guidelines, sketched a project . . . More than the task of a single individual, it was like a manifesto, a call for papers, a large scale project . . .” (p. 87).

In developing his methodology of research programs, the philosopher of science Imre Lakatos identified two key properties that are relevant in the present context (Lakatos 1970). The first is that research programs revolve around a ‘core’ which has a logico–empirical character and is viewed as being irrefutable. In the case at hand, the core would be the empirical observation that, under certain experimental conditions, preschoolers differ from adults in the way they interpret sentences containing QNPs and negation, an observation that has now been replicated many times, and thus cannot be refuted. Another important property of research programs is that are not evaluated in terms of right or wrong. Instead, programs are regarded as either fertile or sterile, or ‘progressive’ and ‘degenerative’ to use Lakatos’ own terminology. To quote Boeckx again “progressive programs generate new families of questions, create new problems and conflicts, which they may or may not solve, but which might have gone unnoticed without the crucial change in perspective which programs typically generate” (p. 90).

Viewed as a research program built around a ‘core’ developmental observation, Isomorphism seems to possess the hallmarks of a progressive one. Indeed, over the last decade, the body of work addressing the phenomena uncovered by Musolino (1998) and its broader implications has grown, spawning new studies and establishing new links between different research areas. In trying to organize these developments, I find it useful to think about them as falling in four categories: (a) implications for models of language acquisition, (b) rapprochement between different research areas, (c) implications for linguistic theory, and (d) reconsideration of prior assumptions. In the remainder of this section, I discuss these developments by reviewing key studies in each of these four categories.

Beginning with (a), recall that the results of Musolino’s (1998) study were initially taken as evidence supporting a Chomskyan/UG model of language acquisition. To quote Musolino (1998), “To the extent that this goal is achieved, the present investigation emphasizes the role played by the theory of Universal Grammar and language learnability in helping us understand language development and its biological basis” (p. 2). With the demise of the grammatical account, claims regarding implications of OI for UG-based models lost steam. At the same time, other researchers interested in the isomorphic puzzle offered different accounts of the facts uncovered by Musolino (1998). For example, Gennari and MacDonald (2005/2006) proposed a constraint-based account of quantifier scope interpretation in children inspired by recent models of language production and comprehension in adults. They key difference between Musolino’s (1998) original account and the one proposed by Gennari and MacDonald is that children’s non-adult behavior is regarded as reflecting their sensitivity to distributional patterns of language use rather than the operation of UG-constrained parameters.

Notice that the garden-path approach to OI discussed in Sect. 3.2 is in principle compatible with Gennari and MacDonald’s constraint-satisfaction account. Yet a different account of OI was offered by O’Grady (2008) who proposed what he called a “processor-based emergentist” account of the facts. The main idea underlying O’Grady’s account is very similar in spirit to Reinhart (2006), Tunstall (1998), and Anderson (2004) in that it views non-isomorphic interpretations as computationally costly from the point of view of the parser. Again, this account doesn’t seem too different from Musolino and Lidz’s (2003, 2006) garden-path approach (see Sect. 3.2). A key difference between O’Grady’s (2008) account and the one proposed

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1Another point made by Gualmini with which I agree is that the approach discussed in Musolino and Lidz (2006) which tries to relate preschoolers’ isomorphic behavior in the case of sentences like Every horse didn’t jump over the fence to their difficulty with scalar implicature (e.g., Noveck, 2001; Papafragou and Musolino, 2003) is problematic.
by Gennari and MacDonald (2005/2006) is that on the emergentist view, the frequency of certain sentences in the input, or certain sentence-interpretation pairings, is a consequence of children's interpretive preferences rather than their cause. In other words, certain interpretations are difficult, and sentences with those interpretations are rare, because of the way the parser is designed to operate.

Parsing considerations, in turn, lead us to (b), the idea that Isomorphism—qua research program—calls for a rapprochement between the fields of language development and language processing. In a 1998 review article on ambiguity in sentence processing, Gerry Altmann raised the following as an outstanding question: Do children process ambiguous sentences in qualitatively the same way as adults do? (p. 151). Since then a growing body of work on children’s real time language comprehension has emerged, directly bearing on Altmann’s question (Trueswell et al. 1999; Snedeker and Trueswell 2004; Snedeker and Yuan 2008; Huang and Snedeker, in press; among others). What this work reveals is that by and large, preschoolers process language the way adults do. In both cases comprehension is incremental in the sense that listeners do not wait until the end of a sentence to generate hypotheses about its meaning, and like adults, children use multiple sources of information to constrain parsing and converge on the most likely analysis of an unfolding sentence.

However, there are also important differences between the two populations. Snedeker (2009) summarizes the situation as follows: “Preschoolers and adults are different in some respects: children make poorer use of context, are slower to inhibit competing alternatives, and have difficulty revising their interpretation in light of conflicting evidence. One is tempted to conclude that changes in language processing during the school years largely reflect the development of control processes.” In this regard, work on Isomorphism—which is about how children resolve scopal ambiguities—can be very informative and add to this growing body of work. For one thing, the facts that we discussed throughout this chapter fit well with the overall picture described by Snedeker, and thus allow us to broaden the empirical basis upon which claims regarding the development of sentence processing abilities can be evaluated. An important question that remains to be directly addressed in the case of Isomorphism is the extent to which the computational costs associated with non-isomorphic interpretations already reported to affect real time comprehension in adults (e.g., Tunstall 1998; Anderson 2004), can also be measured in children, thereby lending support to the garden-path approach to OI discussed in Sect. 3.2.

In sum, a phenomenon that was initially believed to represent a case of grammatical development, explained in terms of parameter setting and the subset principle, turned out to offer, as more results surfaced, a window onto the developing language comprehension system. In the process, old views were abandoned, and new questions and ideas emerged—e.g., the garden-path approach, the QAR—as links between the area of language development and language processing began to crystallize. As mentioned earlier, this shift in perspective also gave rise to work exploring the roots of Isomorphism in adults, Conroy (2008), and the role played by priming in the development of this comprehension process (Vigau, Lidz, and Musolino 2010).

Let us now consider (c), the implications of Isomorphism for linguistic theory. The main idea that I would like to illustrate here is that Isomorphism can be used as a tool to shed light on a number of issues of theoretical interest to linguists as well as developmental psychologists. To begin, consider the question of why children behaved isomorphically in Musolino’s (1998) study. As pointed out by Musolino (1998), this observation is compatible with the fact that children rely on the linear arrangement between NPs and negation to determine their relative interpretation. To be sure, subject NPs precede negation in English and object NPs follow it, which may account for why children tend to interpret subjects outside the scope of negation and objects within its scope. The rule here would be something like: material that follows negation is interpreted within its scope. Another possibility, of course, is that children pay attention to surface c-command relations. In this case, the rule would be: material that falls in the surface c-command domain of negation is interpreted within its scope. However, notice that since objects, but not subjects, are c-commanded by negation in the surface string, an account of children behavior in terms of c-command or linear order makes the same predictions.

In order to tease apart the effects of linear order and c-command, Lidz and Musolino (2002) tested preschoolers in two languages: English and Kannada (Dravidian). Kannada represents an ideal testing case for the issue at hand because sentences like Cookie Monster didn’t eat two slices of pizza are ambiguous in this language in the same way that they are in English, but because Kannada is an SOV language, linear order and c-command relations, at least as far as objects and negation are concerned, are not confused. Thus, whereas in English objects both follow and are c-commanded by negation, in Kannada, objects are c-commanded by negation, but they precede it. What this means is that to the extent that Kannada-speaking-4-year-olds, like their English-speaking counterparts, display a preference for one of the two readings of sentences like Cookie Monster didn’t eat two slices of pizza, an account of that preference in terms of an overreliance on surface c-command relations predicts that we should find the same pattern as in English—because c-command relations between the object and negation are the same in both languages—whereas an account of children’s preference in terms of an overreliance on linear order, predicts opposite patterns in the two languages because objects follow negation in English but they precede it in Kannada.

What Lidz and Musolino (2002) found is that Kannada-speaking-4-year-olds do indeed display a significant preference for one of the two readings of ambiguous sentences like Cookie Monster didn’t eat two slices of pizza but, more importantly, that the patterns are identical in Kannada and English. This result, in turn, demonstrates that preschoolers' preferences are constrained by surface c-command relations, and not linear order. Notice that this conclusion holds, regardless of what causes children to differ from adults. Thus, Lidz and Musolino (2002) used the kind of systematic difference between children and adults uncovered by Musolino (1998).

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9For a similar approach involving different linguistic phenomena, see Solan (1983) and Crain et al. (2002).
as a way to find evidence in children's linguistic representations for the hierarchical structure and the abstract relations defined over these structures (i.e., c-command) that linguists take to be at the heart of our grammatical knowledge.

In a similar vein, Lidz and Musolino (2005/2006) used the kind of behavior reported by Musolino (1998) to shed some light on the theory of indefinites. Such theories vary with respect to whether these NPs can be treated as quantificational (Chung and Ladusaw 2004; Diesing 1992; Fodor and Sag 1982; Heim 1982; Kamp 1981; Kratzer 1995; van Geenhoven 1995). These considerations introduce a potential complication regarding the interpretation of Lidz and Musolino's (2002) conclusion that 4-year-olds have difficulty accessing the wide scope interpretation of numerically quantified NPs – indefinites – in sentences like Cookie Monster didn't eat two slices of pizza. The possibility explored by Lidz and Musolino is that children treat numerically quantified NPs as quantificational and that they have a bias to interpret quantified NPs in general isomorphically. An alternative interpretation is that children disprefer non-isomorphic interpretations in this case because they treat indefinites as individual variables bound by VP-internal existential closure, i.e., as non-quantificational.

To tease apart these two hypotheses, Lidz and Musolino (2005/2006) tested preschoolers on their interpretation of sentences containing numerically quantified NPs in subject position, e.g., Two butterfly didn't go to the city. On the non-quantificational analysis, children should treat indefinite subjects the way they treat indefinite objects and interpret both within the scope of negation. By contrast, on the quantificational analysis, one would expect interpretation to vary as a function of syntactic position. What Lidz and Musolino (2005/2006) found is that the latter conclusion is supported by the data, suggesting that indefinites can be quantificational for children, and presumably for adults as well. In a similar vein, Han, Lidz, and Musolino (2007) used the way preschoolers and adults interpret sentences containing QNPs and negation to shed some light on the question of whether Korean is a verb-raising language.

Finally turning to (d), the research program that grew out of Musolino's (1998) study has also led to a reconsideration of prior assumptions in the areas of experimental methodology and learnability theory. Regarding the latter, a core principle of Crain and Thornton's (1998) Modularity Matching Model is a learnability constraint called the Semantic Subset Principle (SSP). In a nutshell, the SSP guides children in the acquisition of semantics by ensuring that they do not fall prey to the learnability traps associated with ambiguous sentences whose readings asymmetrically entail one another. The SSP predicts that children will learn the meaning of such sentences in a piecemeal fashion, starting with the entailing reading, and adding the entailed reading on the basis of subsequent evidence from the input. A textbook example of such a sentence is one like Every horse didn't jump over the fence where the isomorphic reading, (every > not) asymmetrically entails the non-isomorphic reading (not > every).10

A consequence of this fact is that the way children interpret sentences containing QNPs and negation directly bears on the predictions of the SSP. Trying to work out these predictions, in turn, naturally leads to a systematic evaluation of the logical basis of the SSP as well as its empirical coverage. This is yet another case where isomorphism as a research program forces us to ask new questions and reconsider old assumptions. In doing so, Musolino (2006a, b) offered a detailed evaluation of the SSP and concluded that its logic and current implementation were flawed and that the empirical evidence supporting such a putative constraint was in fact nonexistent. Interestingly, Gualmini (2008) takes issue with this conclusion on the grounds that the isomorphic pattern reported by Musolino (1998) does not represent an accurate picture of the data now available, and therefore that there is no real threat to the SSP. What Musolino (2006) showed, however, is that the problems faced by the SSP run much deeper and that in all probability semantic subset problems of the type discussed by Crain and Thornton do not exist in the first place. Moreover, even if they did, none of the facts currently available in the area of quantifier-negation interaction, regardless of how one wants to characterize them, support a constraint like the SSP in any way. Furthermore, it is worth pointing out that Gualmini himself has also embraced the general conclusion reached by Musolino (2006), namely that we do not need the SSP (Gualmini and Schwarz 2009).

To end this section, let us now consider some of the methodological implications of Isomorphism (as a research program) for another central piece of Crain and Thornton's methodology, namely the Truth Value Judgment Task. There has been a perception in the field, no doubt reinforced by some of Crain and Thornton's impressive results, but also by specific claims these authors made, that the TVJT is in a way bulletproof and guarantees results that cannot be attributed to performance factors. To be sure, Crain and Thornton confidently assert that preschoolers are extremely charitable creatures, and that the TVJT all but guarantees that one will uncover unfiltered grammatical knowledge, as can be seen in the two quotes below:

In our experience with children, we have been able to indentify several factors that conspire to determine which reading of an ambiguous sentence is selected ... First, children pick the reading that makes an ambiguous sentence true in the context ... the assumption is that children want the puppet to say things that are true. That is, the child prefers to say "yes" if possible. (p. 211)

[The TVJT is] relatively free from the influence of performance factors ... Even when children's behaviour differs from that of adults, ... the responses can be confidently attributed to linguistic knowledge and not to performance factors. (p. 4)

It is worth pointing out that these very considerations led Musolino (1998) and then Musolino et al. (2000) to reject a performance account of children's non-adult behavior regarding the interpretation of ambiguous sentences containing QNPs and negation, and to favor instead the competence account discussed in Sect. 2.3. In the case of sentences like Every horse didn't jump over the fence, the reasoning was that

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10Indeed, if it is true that none of the horses jumped over the fence, it necessarily follows that not all of them did.
adults have a preference for the non-isomorphic reading, (not>every), and that in the relevant experiment (see Sect. 2.2), that reading was true in the context of the story that children heard. Thus, given the assumptions illustrated in Crain and Thornton’s quotes, if children possessed the right grammar, they would certainly have accepted such sentences when tested with the TVT. The fact that they didn’t invites is in large part what led Musolino et al. (2000) to conclude that children must not possess an adult-like grammar. Clearly what we have learned since Musolino’s (1998) original results leads to a different conclusion, and underscores the fact that overconfidence in one’s own methodology can lead to erroneous interpretations of developmental patterns, as discussed in more detail in Musolino and Lidz (2006).

6 Concluding Remarks

In the preface to Words and Rules, Steven Pinker tells us that his book tries to illuminate the nature of language and mind by focusing on a particular phenomenon and examining it from every angle imaginable. My goal is this chapter has been more modest, but the approach I have chosen is the same. I picked a specific topic within the acquisition of semantics and focused on what might at first glance look like an arcane generalization about the way preschoolers interpret sentences containing QNPs and negation. But as Pinker reminds us, seeing the world in a grain of sand is often the way of science. Thus, building on Musolino’s (1998) original observation, I have shown that examining the way children handle quantificational interactions can illuminate much broader issues in domains such as linguistic theory, learnability theory, language development, experimental methodology, and the development of sentence processing and pragmatic abilities. Indeed, construed as a research program, Isomorphism provides a productive platform where new work on a variety of issues and topics of interest to linguists, psycholinguists, and developmental psychologists continues to be produced and to create new links between the different areas involved. As discussed earlier, there is currently a debate regarding whether reliance on surface scope has its place as a legitimate factor in our theories of language acquisition—the narrow notion of Isomorphism—but whatever the answer to this question turns out to be, we can expect that it will leave little impact on the overall enterprise, just like the demise of the grammatical account proposed by Musolino (1998) and Musolino et al. (2000) didn’t put an end to work on Isomorphism. In the end, what matters is not that we always find the right answers, but that we continue to try to interest questions.

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