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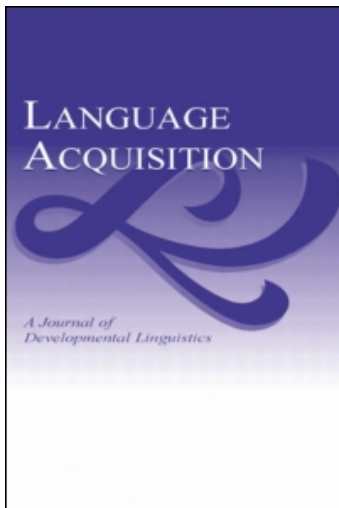
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ARTICLE

Priming of Abstract Logical Representations in 4-Year-Olds

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Though preschoolers in certain experimental contexts strongly prefer to interpret ambiguous sentences containing quantified NPs and negation on the basis of surface syntax (e.g., Musolino's 1998 "observation of isomorphism"), contextual manipulations can lead to more adult-like behavior. But is isomorphism a *purely* pragmatic phenomenon, as recently proposed? In Experiment 1, we begin by isolating the contextual factor responsible for children's improvement in Musolino & Lidz (2006). We then demonstrate in Experiment 2 that this factor can be used to prime inverse scope interpretations. To remove pragmatics from the equation to the extent possible, we show in Experiment 3 that the same effect can be achieved via semantic priming. Our results represent the first clear evidence for priming of the abstract logico-syntactic structures underlying these interpretations and, thus, highlight the importance of language processing alongside pragmatic reasoning during children's linguistic development.

1. INTRODUCTION

In recent years, children's comprehension of sentences containing quantified expressions has been the focus of a growing number of studies on the acquisition of semantics. An intriguing observation emerging from this body of work is that preschoolers, who are otherwise linguistically savvy, often interpret quantified statements in strikingly non-adult-like ways (see

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Crain 2000; Musolino 1998, 2006b for reviews). This observation—and, more generally, the existence of any systematic difference between children and adults—raises two fundamental questions. The first is *causal* and concerns the nature of the observed differences between the two populations. The second is *developmental* and concerns how children ultimately come to interpret quantified sentences the way adults do.

In this article, we address both questions by focusing on a well-documented phenomenon known as “isomorphism,” which expresses the observation that preschoolers, unlike adults, often interpret ambiguous sentences containing quantified noun phrases (QNPs) and negation on the basis of the surface syntactic position of these elements (Musolino 1998; Musolino et al. 2000; Lidz & Musolino 2002, 2005/2006; Gualmini 2004, 2008; Hulsey, Hacquard, Fox & Gualmini 2004; Gennari & MacDonald 2005/2006; Musolino 2006a, 2006b; Han, Lidz & Musolino 2007; Gualmini, Hulsey, Hacquard & Fox 2008; O’Grady 2008). For example, children across several experiments interpret sentences like (1) as meaning (2a) but not (2b):

- (1) Every horse didn’t jump over the fence
- (2) a. ‘No horse jumped over the fence’
b. ‘Not every horse jumped over the fence’

Specifically, we use comprehension-to-comprehension priming as a novel way to probe the roots of isomorphism, thereby addressing the causal question as well as shedding new light on the developmental question, as they pertain to this phenomenon. In doing so, we test the predictions of two recent accounts of isomorphism, one viewing the phenomenon as caused by a single pragmatic factor—the “pragmatics only” view (Hulsey et al. 2004; Gualmini et al. 2008)—and the other by the interaction of pragmatic and processing factors—the “pragmatics + processing” view (Musolino 2006b; Musolino & Lidz 2006). The use of priming as a probe additionally allows us to home in on the kinds of syntactic and semantic representations that children build in interpreting these sentences and how these representations persist for learning and memory.

We take as a point of departure for our investigation a study by Musolino & Lidz (2006) demonstrating that the manipulation of certain contextual features can lead to more adult-like behavior on the part of preschoolers, and thus that pragmatics must be implicated in the explanation of isomorphism (see also Gualmini 2004). In Experiment 1, we begin by isolating more precisely the pragmatic factor responsible for the improvement reported by Musolino & Lidz (2006). Our finding here, that the nature of the expectations created by the story children are shown directly impacts how they interpret ambiguous statements describing what happened in the story, is compatible with both the “pragmatics only” and the “pragmatics + processing” views.

In Experiment 2, however, we turn the tables on the “pragmatics only” account, and demonstrate that the kind of pragmatically supportive contexts uncovered in Experiment 1 can be used to reveal the role of the language processor in the reduction of isomorphic behavior. Specifically, we show that given an ambiguous statement *S* with readings *A* and *B*, accessing the dispreferred reading *B* in pragmatically supportive contexts can prime preschoolers to then access *B* later in less supportive contexts. To further investigate this kind of priming, and remove pragmatics from the equation to the extent possible, we show in Experiment 3 that the same effect can be achieved by priming children with *unambiguous* sentences that have the same truth conditions as dispreferred reading *B* and are used *in pragmatically unsupportive contexts*.

We conclude that isomorphism does not have a single root cause. The pragmatic features brought to light by Gualmini and colleagues undoubtedly represent one important contributing factor in explaining isomorphism in certain experiments. But, critically, they are not the only contributing factors. More importantly, our results document the first clear evidence for priming of the logico-syntactic structures underlying the interpretation of quantified statements. This conclusion is worth emphasizing, especially in light of the abstract nature of the representations involved, the fact that such priming can be observed in children (see Huttenlocher, Vasilyeva & Shimpi 2004; Bencini & Valian 2008; and Snedeker & Thothathiri 2008 for related evidence), and the observation that priming, as a general phenomenon, has been much more elusive in comprehension than in production (Branigan 2007). Moreover, on the view that priming is a form of implicit learning (Bock & Griffin 2000; Branigan 2007), we have evidence for the role of experience, in addition to developmental changes in discourse sensitivity, as a possible solution to the developmental question of how children become adult-like in their interpretation of scopally ambiguous expressions. Thus, considered together, our results highlight the importance of language processing alongside pragmatic reasoning during children's linguistic development.

2. BACKGROUND

Consider the ambiguous sentences below along with their logical representations.

- (3) Every horse didn't jump over the fence
 a. $\forall x$ [horse (x) \rightarrow \neg jumped over the fence (x)]
 b. $\neg\forall x$ [horse (x) \rightarrow jumped over the fence (x)]
- (4) The Smurf didn't catch two birds
 a. $\neg\exists_2x$ [bird (x) \wedge caught (Smurf, x)]
 b. \exists_2x [bird (x) \wedge \neg caught (Smurf, x)]

In each case, two scope readings are possible. In (3), when the quantified subject is interpreted outside the scope of negation, the sentence can be paraphrased as 'Every horse is such that it didn't jump over the fence' (every > not), i.e., none of the horses jumped over the fence (3a). This reading is called an *isomorphic* interpretation since the scope relation between the quantified subject and negation can be directly read off of their surface syntactic position. Notice that (3) can also be paraphrased as 'Not every horse jumped over the fence' (not > every), in which the quantified subject is interpreted within the scope of negation (3b). This is called a *non-isomorphic* interpretation since in this case surface syntactic scope and semantic scope do not coincide. Similarly, (4) can either be paraphrased as 'It is not the case that the Smurf caught two birds' (not > two), an isomorphic interpretation (4a), or 'There are two birds that the Smurf didn't catch' (two > not), a non-isomorphic interpretation (4b).

Several studies on the acquisition of quantification have shown that when given a Truth Value Judgment Task (TVJT), preschoolers, unlike adults, display a strong preference for the isomorphic interpretation of sentences like (3–4) (Musolino 1998; Musolino et al. 2000; Lidz & Musolino 2002; Musolino & Gualmini 2004; Noveck et al. 2007, among others). This is what Musolino (1998) called "the observation of isomorphism" (OI). Earlier accounts of the

phenomenon (e.g., Musolino 1998; Musolino et al. 2000) viewed OI as reflecting a grammatical difference between preschoolers and adults. However, more recent evidence has emerged that casts serious doubt on the hypothesis that children lack the grammatical operations required for inverse scope. Specifically, it has been shown that (i) in sentences that require the grammatical operations associated with inverse scope but lack a scope ambiguity, children behave identically to adults (Lidz et al. 2004; Syrett & Lidz 2004); (ii) in multiply quantified sentences lacking negation, preschoolers access inverse scope interpretations at adult-like levels (e.g., Goro 2007); (iii) in certain cases, OI can also be induced in adults (Musolino & Lidz 2003; Conroy 2008); and finally (iv) certain contextual manipulations can lead children to behave more like adults, i.e., to access non-isomorphic interpretations at a much higher rate (Musolino 2000; Gualmini 2004; Musolino & Lidz 2006).

For example, Musolino & Lidz (2006) examined children's ability to access the non-isomorphic (i.e., 'not all') interpretation in two conditions: a no-contrast condition designed to replicate the original Isomorphism Effect ((5a) in the context of Figure 1a), and a contrast condition ((5b) in the context of Figure 1b).

- (5) a. Every horse didn't jump over the fence
 b. Every horse jumped over the log, but every horse didn't jump over the fence

Notice that in both conditions, these sentences are true on the non-isomorphic interpretation (i.e., 'not all of the horses jumped over the fence'), since only 2 out of the 3 horses jumped over the fence, and they are false on the isomorphic interpretation (i.e., 'none of the horses jumped over the fence'), since it is not the case that none of the horses jumped over the fence. What Musolino & Lidz (2006) found is that children's ability to access the non-isomorphic interpretation significantly improved in the contrast condition, (5b), compared to the no-contrast condition, (5a).

One hypothesis is that the improvement was due to the presence of the explicit contrast in (5b), "Every horse jumped over the log, but..." which is absent in (5a). Another possibility is that the improvement was due to the way that negative sentences contribute to a discourse. There is general agreement that the discourse function of negative sentences is to express the

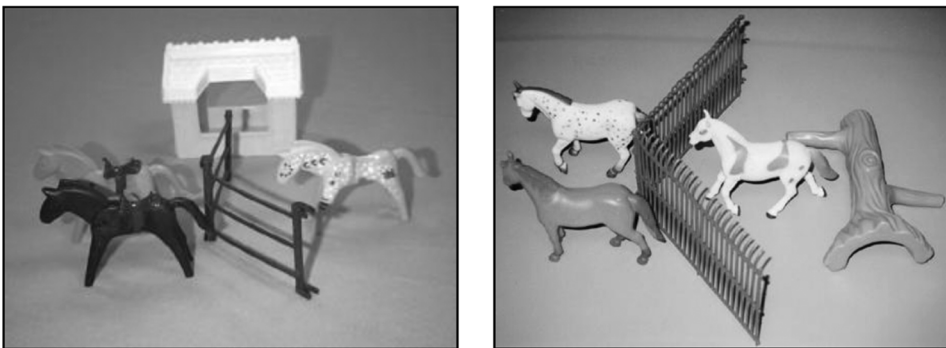


FIGURE 1 Experimental conditions in Musolino & Lidz (2006): (a) No-contrast (left) and (b) Contrast (right).

fact that something about the situation is contrary to expectations (e.g., Wason 1965; de Villiers & Tager Flusberg 1975; Horn 1989). However, given the experimental scenario associated with (5a), neither reading of the sentence was the negation of a positive expectation set up by that scenario. In these contexts, which we will call “early failure” (EF), the horses first consider—but then reject—jumping over a barn. They then consider jumping over the fence, and 2 of 3 succeed (see Figure 1a). Because the context did not create a positive expectation that *all* of the horses would jump over the fence—since they initially all failed to jump over the barn—the non-isomorphic reading may have been a poor fit to the context. In contrast, in the scenarios associated with (5b), which we will call “early success” (ES), all of the horses first successfully jumped over the log, presumably setting up the expectation that they will all jump over the fence as well (see Figure 1b). The inverse scope reading, i.e., ‘not all the horses jumped,’ thus represented the negation of the expectation that all the horses would jump. Notice now that the two conditions in Musolino & Lidz (2006) confounded the contribution of the discourse context with the contribution of the explicit contrast. Indeed, in (5a), the sentence contains no explicit contrast and was presented in an EF context. In (5b), the sentence contains an explicit contrast and was presented in an ES context. Consequently, we are unable to determine whether the improved access to non-isomorphic interpretations derived from the presence of the explicit contrast or from the ES context.

In this regard, Gualmini et al. (2008) (following Hulsey et al. 2004) recently proposed an account of children’s scope preferences that essentially treats isomorphism as an epiphenomenon and reduces the effect to the kind of pragmatic considerations discussed above. 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 TVJT). 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. If both interpretations are good answers to the QUD, then children adhere to the Principle of Charity and choose the true interpretation. Crucially, on this view, nothing other than the mechanism just described is needed to account for children’s non-isomorphic behavior (e.g., no parsing preference for surface scope, no inability to revise initial parses, etc.). In other words, isomorphism is a purely pragmatic phenomenon that reduces to the operation of a single causal factor (Gualmini 2008).¹ To quote Gualmini: “In particular, we need to consider the possibility that once the role of context is formalized, we might have a

¹In fact, Gualmini (2008) makes the following additional claims: (i) that “isomorphism” often makes the wrong empirical predictions, and (ii) that “isomorphism” is not even adequate as a description of the data, as there are documented cases where children do not behave isomorphically. Crucially, however, these two claims rest on a fundamental misinterpretation of what Musolino (1998) intended by “isomorphism” and endow a simple descriptive label with powers that it was never intended to have. First, as explicitly emphasized by Musolino (1998, Section 2.4), “the *observation* of isomorphism” is only a descriptive generalization, not a principle, and so it makes no sense to talk about the “predictions of isomorphism.” Second, “isomorphism,” as a descriptive label, was meant to apply to the cases discussed by Musolino (1998). It was already well-known at the time that there were many cases where children did not behave “isomorphically” (see Musolino 1998 for discussion) but this was, and remains, irrelevant. At any rate, the arguments presented here go through regardless of the validity of the claims in (i) and (ii).

mechanism that makes other factors unnecessary—including the putative preference for surface scope (2008, 1168).” We call this the “pragmatics only” account.

As an anonymous reviewer notes, the discussion in Hulsey et al. (2004) does not provide an algorithmic way of determining what the salient QUD is in a given context, and the same seems to be true in the discussion of Gualmini et al. (2008). As far as we can tell, Hulsey et al. (2004) simply state that, when not overtly mentioned by the experimenter, the QUD must be inferred based on contextual cues (72). In addition, determination of the QUD must be made on a trial-by-trial basis (79). Gualmini et al. (2008) specify that the QUD should be conceived of as “any question to which only the possible outcome and the actual outcome [of a story] are possible answers (214).” Indeterminacy with respect to the mechanism by which a particular QUD is chosen in context has non-trivial consequences for whether the QAR can account for the interpretive preferences that children are shown to have in Section 3 following EF and ES stories, independent of our priming manipulation. The real concern here is that, absent a precise way of restricting the salient QUD, the QAR may be unfalsifiable. Nevertheless, assuming this issue can be overcome, we strive throughout the paper to explicitly formulate the QUDs that may plausibly be made salient in our stories in order to better evaluate the QAR alternative to our account.

Returning to the Musolino & Lidz (2006) study, it is entirely plausible that EF contexts gave rise to a QUD for which the non-isomorphic reading is not a good answer—hence children’s failure to access the non-isomorphic interpretation. For example, suppose the QUD for the no-contrast story depicted above was something to the effect of “Did any horses jump over the fence?” The isomorphic interpretation of the test sentence “Every horse didn’t jump over the fence” entails a No answer to that QUD (since no horses jumped on that interpretation), while the non-isomorphic interpretation of the test sentence implies but does not entail a Yes answer to that QUD (since that interpretation is compatible with either some horses having jumped or no horses having jumped). Therefore, according to the QAR, given that the non-isomorphic interpretation does not entail either a Yes or a No answer to the QUD, only the isomorphic interpretation addresses the QUD. Children are thus led to choose the isomorphic interpretation and reject the test sentence because that interpretation is false in context.

On the other hand, perhaps the ES contexts gave rise to a QUD for which the non-isomorphic reading was a good answer—hence the decrease in isomorphic behavior. For example, let us imagine that the contrast story depicted above made salient the QUD “Did all of the horses jump over the fence?” In this case the isomorphic interpretation of the ambiguous second clause in the test sentence “Every horse jumped over the log, but every horse didn’t jump over the fence” entails a No answer to that QUD. If no horses jumped over the fence (the isomorphic reading), then it is necessarily false that all of the horses jumped. Similarly, the non-isomorphic interpretation also entails a No answer to that QUD. If not all of the horses jumped (the non-isomorphic reading), then plainly it is false that all of the horses jumped. Here, the Principle of Charity is, by hypothesis, decisive, leading children to choose the latter interpretation because it alone makes the target sentence true in context.

However, acknowledging that pragmatics may play such a role in the explanation of isomorphism does not necessarily mean that other, non-pragmatic factors aren’t also involved. Thus, an alternative to the QAR views isomorphism as being caused by the interaction of pragmatics and processing factors (Musolino & Lidz 2003, 2006). We call this the “pragmatics + processing” view.

The preceding discussion raises two new questions. First, is the improvement reported by Musolino & Lidz (2006) due to story type (i.e., ES vs. EF) or the presence of an explicit contrast? Second, to the extent that story type is the relevant factor, is isomorphism a purely pragmatic phenomenon deriving from the QUD, as proposed by Hulsey et al. (2004) and Gualmini et al. (2008)? We now turn to three experiments designed to address these issues, thereby testing the predictions of the “pragmatics only” and “pragmatics + processing” views and shedding new light on the broader causal and developmental questions.

3. EXPERIMENTS

3.1. Experiment 1: Contrast vs. ES Story Type

Recall that in Musolino & Lidz (2006) the addition of a preceding affirmative statement (e.g., *Every horse jumped over the log...*) was found to improve children’s access to the non-isomorphic interpretation of ambiguous negative statements (e.g., ... *but/and every horse didn’t jump over the fence*).² Nevertheless, it was unclear whether the observed improvement was due to the presence of an explicit contrast in test sentences or, rather, to an accompanying change in story type. Test sentences with contrasts always followed ES stories, in which three characters all initially succeeded in performing an action, but then only two of the three characters managed to perform the second action.

On the other hand, test sentences without explicit contrasts in the replication condition always followed traditional EF stories, in which three characters all initially failed to perform the first action, and then two of the three characters performed the second action (like stories in previous work documenting the Isomorphism Effect, e.g., Musolino 1998; Musolino, Crain & Thornton 2000).

To tease apart the effects of contrast and story type in the current experiments, we held story type constant—all stories were of the ES type—and manipulated the presence or absence of explicit contrasts before negative statements.

3.1.1. Participants

We tested 20 English-speaking children between the ages of 4;01 and 4;11 (8 boys, 12 girls, mean age = 4;05, $SD = 3.2$ mo.). Data from 4 additional children were excluded due to excessive failure on control stories ($n = 2$) or for reasons of counterbalancing ($n = 2$).

3.1.2. Materials

Participants were randomly assigned to either of two conditions, a contrast condition and a no-contrast condition. In the contrast condition, they judged 3 contrast statements (6a) and 3 no-contrast statements (6b). In the no-contrast condition, they judged 6 no-contrast test sentences (6b).

- (6) a. Every horse jumped over the cow, but every horse didn’t jump over the pig
 b. Every horse didn’t jump over the pig

²Note that this was found to be true whether the ambiguous negative statement was introduced by *but* or *and*.

These sentence types both contain a scopal ambiguity (*Every horse didn't jump over the pig*) but differ in terms of whether the scopally ambiguous clause is preceded by an affirmative statement with which it contrasts. Each participant was presented with 6 test sentences and 5 control sentences in pseudorandom order. Sentence order was counterbalanced across subjects. Control sentences were unambiguous in context, containing either a universal quantifier in subject position (7a) or negation (7b), but never both.

- (7) a. Every sheep [found a penny (True)/bought candy (False)]³
 b. The beetles [didn't look in the cave (True)/didn't look in the tree (False)]

Each control sentence had both true and false versions [in brackets above] in order to allow the experimenter to elicit variable responses (yes or no) based on how participants responded to preceding test sentences, as explained in more detail below. A complete list of test and control sentences can be found in Appendix A.

3.1.3. Procedure

The method used in all three experiments was the Truth Value Judgment task (TVJT) (Crain & Thornton 1998). In this task, one experimenter told a series of stories using toys and props, and a second experimenter played the role of a puppet who watched alongside the children.⁴ After each story, the puppet said what she thought happened in the story. The puppet first summarized the story (e.g., *That was a story about...*) and then described what she thought happened using the target/control sentences. The child's task was to tell the puppet whether she was right or wrong. Before any of the stories were told, the rules of the task were explained: if the puppet is right, she gets a cookie; if she is wrong, she gets a sip of milk. Children were told that the puppet likes both types of snacks (though only one at a time), and they were encouraged to justify their answers. The experimenter acting as puppeteer recorded children's responses and justifications. Children were always tested individually.

In order to guard against response bias, two measures were taken. First, participants received brief task-related training, during which they helped the puppet learn her colors, before the study began. The puppet was always wrong once about color and right once about color. Explicit correction was given whenever the child gave the wrong reward during training or showed signs of response bias. We excluded data from participants who could not provide at least one *yes* and one *no* during training. Second, control stories were used to maintain a balance of *yes* and *no* responses throughout each experimental session. For example, if a participant answered *yes* to a given test sentence, the puppeteer would read a false control sentence after the following control story in an attempt to elicit a *no*, and vice versa. We excluded data from children who missed more than one control story and/or who could not give justifications for their answers.

³While *Every sheep found a penny* is ambiguous, strictly speaking, it was not ambiguous in context since in the story it describes there are three different pennies, each of which is found and kept by a different sheep. The same is true for two other such filler sentences: *Every whale played with a ball* and *Every boy put on a hat*.

⁴In Experiment 1, without exception Jeffrey Lidz was the storyteller, and Joshua Viau was the puppeteer, noting children's responses. In Experiment 2, Joshua Viau was always the storyteller, and four different experimenters alternated as puppeteers (Jessica Hicks, Erin Leddon, Jane Solomon, and Kristen Syrett). In Experiment 3, Jobin Mathew, Jane Solomon, and Joshua Viau alternated as both storytellers and puppeteers.

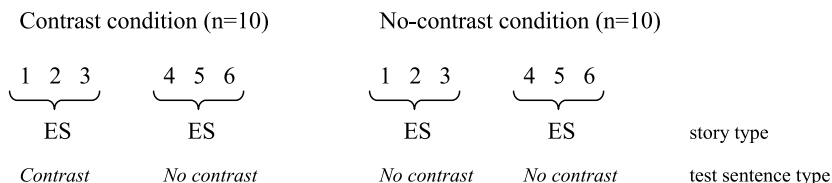


FIGURE 2 Experimental conditions in Experiment 1.

Concerning experimental design, we varied one experimental factor, test sentence type, between participants. In the contrast condition, the first 3 test sentences had explicit contrasts, while the last 3 test sentences lacked explicit contrasts. In the no-contrast condition, all 6 test sentences lacked explicit contrasts. This design is illustrated in Figure 2.

We held the Early Success (ES) story type constant across conditions. In other words, regardless of whether a given story was to be described by a contrast or no-contrast test sentence in either condition, its plot invariably involved three characters all initially succeeding at one task and then only two of the three succeeding at a second task. The following description of a representative test story should make this clear.

(8) Horses (ES)

Three horses decide to have some fun jumping over things. One horse jumps over a cow and then challenges the other two horses to do the same. The other horses jump over the cow one after the other. Then the first horse jumps over the pig and challenges the other horses to do the same. The second horse jumps over the pig. The third horse considers jumping over the pig but decides that the pig looks scared and approaches him. The pig is, in fact, scared, so the third horse just talks with him instead of jumping over him.

Following this story, when the puppet describes what happened using the scopally ambiguous clause *Every horse didn't jump over the pig*, there are two possible interpretations with different truth conditions regardless of whether the ambiguous clause is preceded by an explicit contrast, as shown below.

(9) Truth conditions for test sentences in Experiment 1

False: Isomorphic interpretation (every > not), i.e., 'no horse jumped'

True: Non-isomorphic interpretation (not > every), i.e., 'some but not all horses jumped'

Since two of the three horses jump over the pig in the "Horses" test story, for example, the isomorphic interpretation of *Every horse didn't jump over the pig* is false in context, and the non-isomorphic interpretation is true in context. Thus, children's acceptances and/or rejections of test sentences allow us to clearly infer which interpretation they are accessing.

3.1.4. Results

We predicted that if the improvement in children's ability to access the dispreferred, non-isomorphic interpretation that Musolino & Lidz (2006) reported was due to the presence

of explicit contrasts, then we should observe significantly higher acceptance rates for this interpretation in response to the first 3 test stories in the contrast condition than in the no-contrast condition. Alternatively, if improvement was due to the ES story type, then we predicted no significant difference between these conditions, with acceptance rates at around 50–60%, which corresponds to the acceptance rates reported by Musolino & Lidz (2006).

Furthermore, we predicted that (i) if explicit contrasts did improve access to the non-isomorphic interpretation, and (ii) if this interpretation could be primed by test sentences with explicit contrasts, then the effect of this priming would persist in the contrast condition and could be measured by significantly higher acceptance rates in the last three test stories of the contrast condition relative to the no-contrast condition. Children's percentage acceptance of test sentences, all of which were true on the non-isomorphic interpretation only, is shown for both conditions in Figure 3.

As the figure suggests, we found no significant differences between conditions in children's mean acceptance rates for the first 3 test sentences ($t(18) = 0.16$, $p = .8747$), for the last 3 test sentences ($t(18) = -0.98$, $p = .3401$), or for all 6 test sentences combined ($t(18) = -0.38$, $p = .7084$). Here and in discussions of the experiments to follow, t -tests were run with independent samples, and all p -values reported are two-tailed unless otherwise indicated. Following Jaeger (2008)—who highlights issues with using parametric statistics in the analysis of categorical data—we also performed logistic regressions on our data for this and all subsequent experiments using R's lme4 package (Bates 2005; Bates & Sarkar 2007), with subjects and items as random effects, and prime (or Contrast in Experiment 1) and block (first 3 test vs. last 3 test) as fixed effects. We examined the same effects and contrasts for which t -tests are reported throughout this paper and found identical results in every case.

Across conditions, when children rejected the puppet's statements they typically justified their rejections by emphasizing that two of the three characters did something but one character didn't, e.g., two horses jumped over the pig but one horse talked to him instead. Similarly, when children accepted the puppet's statements their justifications typically highlighted what

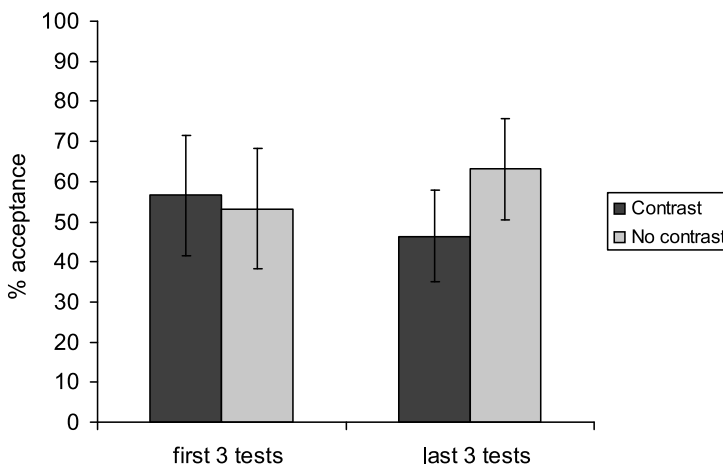


FIGURE 3 Percentage acceptance for test sentences in Experiment 1.

the last character did, e.g., one horse talked to the pig. The variance in children's responses to test items was not distributed bimodally—only 3 subjects in the contrast condition, and 4 subjects in the no-contrast condition, accepted or rejected test sentences across the board. Instead, most children showed variable access to the non-isomorphic interpretation of our test items. On control items children responded correctly 92% of the time in the contrast condition and 96% of the time in the no-contrast condition.

3.1.5. Discussion

In Experiment 1, participants' acceptance rates for the non-isomorphic interpretation were statistically identical in both conditions, hovering near the 60% acceptance rate that Musolino & Lidz (2006) reported with the same ES story type. Thus, our findings replicate those of Musolino & Lidz (2006), confirming that children's failures to demonstrate adult-like performance in interpreting scopally ambiguous sentences do not reflect a lack of grammatical knowledge since these failures can be partially overcome through contextual manipulation. In addition, these results allow us to be more precise about the mechanism by which children improve in their ability to access the non-isomorphic interpretation. Since we held the ES story type constant in Experiment 1, and our manipulation involving explicit contrasts had no effect, we can conclude that some aspect of the ES story type, and not simply the presence of explicit contrasts in test sentences describing this story type, was responsible for the previously observed reduction in the Isomorphism Effect.⁵

Further research would be necessary to determine *how* ES stories lead to higher acceptance rates for our test sentences. A possible explanation concerns the satisfaction of felicity conditions on negative statements. It has long been observed that such statements are significantly easier to process and evaluate when they are used to point out discrepancies between one's expectations about the outcome of an event and the actual outcome (e.g., de Villiers & Tager Flusberg 1975; see also Wason 1965 & Horn 1989). ES stories, in which all three characters succeed in doing one task (e.g., three horses jump over a log), may create just the kind of positive expectation concerning the characters' abilities or performance that is needed to render negative statements that cancel that expectation as felicitous. In comparison, EF stories such as those used in early demonstrations of the Isomorphism Effect create negative expectations concerning characters' abilities (e.g., all three horses fail to jump over the log).⁶

Of course, expectations are merely the starting point of an explanation for children's performance on our task. As discussed in Section 2, these pragmatic effects have been interpreted in different ways. For example, on the "pragmatics only" view, an ES story might be thought

⁵Our results do not rule out an independent effect of test sentences with explicit contrasts. However, it is not apparent how one would test for such an effect in the context of non-ES stories, as would be necessary.

⁶For further demonstrations of the role of such expectations in children's interpretation of scopally ambiguous statements involving negation and the indefinite *some* in object position (e.g., *the detective didn't find some guys*), readers are referred to Gualmini (2004). In addition, note that the non-isomorphic interpretation of our test sentences (e.g., 'Not every horse jumped over the fence') does contrast with the negative expectation established by EF stories since it implies that some horses succeed. Nevertheless, children persist in rejecting this interpretation following EF stories. It may be that the negation of positive expectations—such as those established by ES stories—is simply easier to process than the negation of negative expectations. In other words, not all discrepancies between one's expectations about the outcome of an event and the actual outcome are created equal in terms of their effect on the relative felicity of negative statements describing that event.

of as leading to higher acceptance rates for the non-isomorphic interpretation of *Every horse didn't jump over the fence* because only this interpretation is a good true answer to the most salient QUD in that context, e.g., “Did all of the horses jump over the fence?” (Hulsey et al. 2004; Gualmini et al. 2008). In contrast, we might attribute the improvement to a freeing up of processing resources normally associated with interpreting negative statements, which can then be devoted to revising an initial isomorphic interpretation and generating the non-isomorphic interpretation (Musolino & Lidz 2006).⁷ Thus, the results of Experiment 1 are compatible with both the “pragmatics only” and the “pragmatics + processing” views.

However, these two accounts make different predictions about what role experience may play in overcoming isomorphism. On the “pragmatics only” view, the only factor contributing to children’s responses in these tasks is the match between the context and the test sentence. Children, on this view, simply select the interpretation of the test sentences that is a good answer to the most salient QUD. Accordingly, if this view is correct, in what we have been calling EF contexts, since children behave isomorphically, we must conclude that the non-isomorphic interpretation is not a good answer for the relevant QUD. In contrast, in ES contexts, since children behave in a more adult-like fashion, we must conclude that the non-isomorphic interpretation is a good answer to the QUD.

Thus, this approach predicts that if a child were placed in an ES context followed by an EF context, we should observe a reduction of isomorphic behavior during the ES trials, followed by a return to isomorphic behavior during the EF trials. This prediction follows from the fact that on the “pragmatics only” view, the sole determinant of the child’s interpretation is the context in which the target sentence is heard. If, on the other hand, the processor plays a role in the explanation of isomorphism, we may expect to observe a priming effect in the situation just described. That is, the reduction in isomorphic behavior induced by the ES context might carry over to the EF context. In other words, accessing the non-isomorphic interpretation more often in the ES context would consequently increase the likelihood of accessing the same interpretation in the EF context. Experiment 2 is designed to test this prediction.

3.2. Experiment 2: ES Priming

As discussed above, the goal of Experiment 2 is to begin teasing apart the contributions of pragmatic and processing factors in the reduction of isomorphic behavior, thereby testing the predictions of the “pragmatics only” and “pragmatics + processing” accounts. Specifically, we ask here whether we can use ES stories to *prime* children to access the non-isomorphic interpretation more successfully following EF stories.

3.2.1. Participants

We tested 24 English-speaking children between the ages of 4;00 and 4;11 (9 boys, 15 girls, mean age = 4;07, $SD = 3.2$ mo.). Data from 6 additional children were excluded due to excessive failure on control stories ($n = 5$) or inattention ($n = 1$).

⁷The non-isomorphic interpretation would then be more likely to be chosen because only that interpretation is true in context in our experiments, and children arguably prefer to select the interpretation that makes a sentence true (thereby satisfying the Principle of Charity).

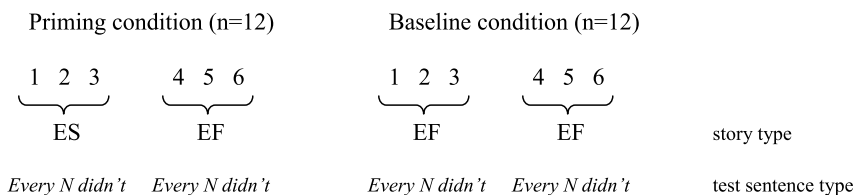


FIGURE 4 Experimental conditions in Experiment 2.

3.2.2. Materials and Procedure

Participants were randomly assigned to one of two conditions. In the priming condition, they were asked to judge 3 test sentences in ES contexts followed by 3 test sentences in EF contexts. In the baseline condition, they were asked to judge 6 test sentences in EF contexts (Figure 4).

Test sentences in both conditions were identical to those used in the baseline condition of Experiment 1 (e.g., (6b) repeated as (10) below):

(10) Every horse didn't jump over the pig

As in Experiment 1, each participant was presented with 6 test sentences and 5 control sentences in pseudorandom order. Sentence order was counterbalanced across subjects. Control sentences were identical to those used in Experiment 1.

As mentioned above, we held the test sentence type constant across conditions. This design ensured that any observed improvement in children's access to the non-isomorphic interpretation of our test sentences over the last three trials could be attributed solely to the effect of experience with them as descriptions of particular stories during the first three trials. A representative example of an EF story is repeated below. For the ES equivalent, refer back to (8).

(11) Horses (EF)

Three horses decide to have some fun jumping over things. One horse suggests jumping over a cow, but the other horses say the cow is too big to jump over, and the plan is abandoned. Then the first horse jumps over the pig, which is much smaller, and challenges the other horses to do the same. The second horse jumps over the pig. The third horse considers jumping over the pig but decides that the pig looks scared and approaches him. The pig is, in fact, scared, so the third horse just talks with him instead of jumping over him.

Following either story type, when the puppet describes what happened using the scopally ambiguous sentence *Every horse didn't jump over the pig*, there are two possible interpretations with different truth conditions as in Experiment 1. As in Experiment 1, only the non-isomorphic interpretation is true in context.

3.2.3. Results

We predicted that (i) if ES stories improved both the relative felicity of negative statements in our test sentences *and* the relative accessibility of the non-isomorphic interpretation of these

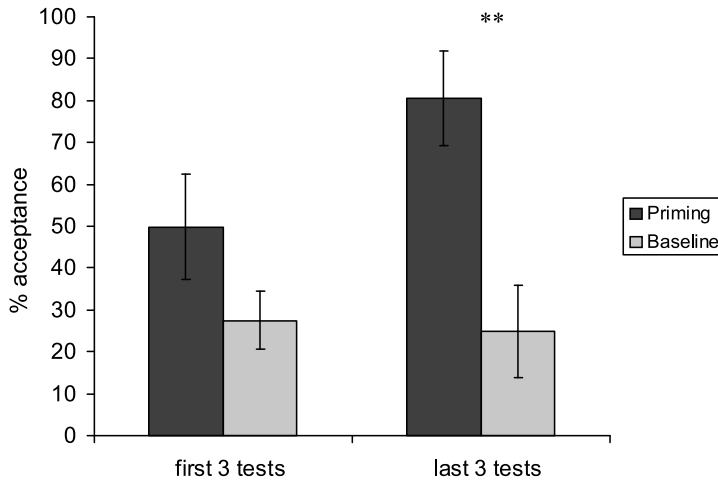


FIGURE 5 Percentage acceptance for test sentences in Experiment 2.

sentences within the language processing system, and (ii) if this interpretation could be primed by ES stories, then the effect of ES priming would persist in the block of three EF stories in the priming condition relative to the baseline condition. Alternatively, if children's past non-isomorphic behavior were due solely to the satisfaction of felicity conditions on negative statements by ES stories, then we predicted no significant difference between our two conditions on the last three stories (since these were all of the EF variety), with low acceptance rates as reported in previous work.

Children's acceptance rates on the test sentences, all of which were true on the non-isomorphic interpretation only, are shown for both conditions in Figure 5.

We found a significant difference between conditions in children's mean acceptance rates for the last 3 test sentences ($t(22) = 3.55$, $p = .0018$). Of the 24 children tested, 13 had variable access to both interpretations of our test sentences, either improving or declining from the first 3 test sentences to the last 3 test sentences. All such children in the priming condition improved ($n = 6$), while children in the baseline condition were at chance in terms of whether they improved or declined ($n = 3$ and $n = 4$, respectively) (Sign test significant for ES only, $p = .0313$).⁸ In addition, the difference between conditions in children's mean acceptance rates for the first 3 test sentences approached significance in a one-tailed test ($t(22) = 1.55$, $p = .0677$), bolstering our earlier claim based on the results of Experiment 1 that ES stories were mainly responsible for children's higher rate of non-isomorphism in previous work (e.g., Musolino & Lidz 2006).⁹ Children's justifications for their acceptances and rejections of the puppet's statements were similar to those described for Experiment 1. On control items children

⁸As with Experiment 1, we also conducted logistic regressions on this data and arrived at the same statistical conclusions.

⁹In fairness, it is impossible to directly compare our results with those obtained by Musolino & Lidz (2006)—despite the similarity of these studies and relevance of the findings of each to the other—due to differences in experimental stimuli and in participants' mean age.

responded correctly 92% of the time in the priming condition and 98% of the time in the baseline condition.

We should pause to consider the fact that children's acceptance rates for the non-isomorphic interpretation seem to show two different "ceilings." In Experiment 1 and on the first trials in the priming condition of Experiment 2, these rates were approximately 50–60%, in line with previous work. However, following priming, children in Experiment 2 improved to 81% on the last three trials, a significant increase compared to acceptance rates for the first three trials (paired samples t -test, $t(11) = -2.73$, $p = .0196$). How should we interpret this difference? We are unable to answer definitively, but we can rule out one possible explanation. Imagine that what truly matters for the development of adult-like competence in interpreting scopally ambiguous sentences is not one specific contextual manipulation per se (e.g., ES stories), but rather the variability of the input in terms of sentence–context pairings. Only the children in the ES condition in Experiment 2 who received input from multiple sentence-story pairings improved significantly on the last three EF stories. Perhaps simply noticing the inconsistency in story type across identical test sentences helps children sort out which interpretation goes with which context, easing the processing burden and allowing the isomorphic and non-isomorphic interpretations to compete on a more equal footing.

If this hypothesis were correct, one would predict equal improvement in a follow-up condition in which participants judged three EF stories followed by three ES stories, i.e., the mirror image of Experiment 2 (with test sentences again held constant). In order to test this prediction, we ran 11 additional English-speaking children between the ages of 4;00 and 4;11 (7 boys, 4 girls, mean age = 4;06, $SD = 3.9$ mo.). The results showed a marginally significant improvement from 18% on the first 3 EF trials to 36% acceptance on the last ES 3 trials (paired samples t -test, one-tailed, $t(10) = -1.61$, $p = .0692$), as one might have expected given the differences observed in how children typically respond to our test sentences in ES contexts relative to EF contexts. However, children's acceptance rates failed to rise to anywhere near the level that participants reached in the priming condition in Experiment 2. These findings cast doubt on a variability account of our priming effect and serve to reinforce the special status of ES stories in terms of boosting access to the non-isomorphic interpretation for children.

3.2.4. Discussion

Recall that Experiment 2 was designed to test the prediction that accessing the non-isomorphic interpretation more often in ES contexts would consequently increase the likelihood of accessing the same interpretation in EF contexts. As our results indicate, this prediction was indeed borne out. In other words, we have shown that ES contexts can be used to prime the non-isomorphic interpretation of ambiguous sentences like *Every horse didn't jump over the fence*, which strongly suggests that the language processor must be implicated in the reduction of isomorphic behavior, contra the "pragmatics only" view.¹⁰

In order to better appreciate this conclusion, it is worth reminding ourselves of the mechanics of the "pragmatics only" account. Recall that the mechanism responsible for variation in isomorphism according to the QAR is variation in the particular QUD that the test stories make

¹⁰Indeed, while the exact nature of priming remains a debatable issue, few would dispute the fact that priming involves the language processor (Branigan 2007).

salient. We concluded earlier that, on this view, it must be the case that EF contexts do not give rise to a QUD to which the non-isomorphic interpretation of our ambiguous test sentences is a good answer since children behave isomorphically in those contexts. Similarly, on this view, it must be the case that ES contexts do give rise to a QUD to which the non-isomorphic interpretation is a good answer since children's behavior is more adult-like in ES contexts. However, it is difficult to see on this view why prior exposure to ES contexts should have any effect on a child's behavior in EF contexts. After all, if all that matters is the QUD, and EF contexts do not give rise to a QUD sufficiently addressed by the non-isomorphic interpretation, then children should always behave poorly in EF contexts, independent of their prior experience with these sentences. Put another way, assuming that EF contexts do not give rise to a QUD compatible with the non-isomorphic interpretation, and given the fact that children behaved in a more adult-like fashion in EF contexts in our priming condition than in our baseline condition, we must conclude that the QUD simply cannot be the sole determinant of isomorphic behavior. Clearly then, the language processor must be implicated in the explanation of isomorphism, as predicted by the "pragmatics + processing" view.

Having shown that access to the non-isomorphic interpretation can be primed, we now need to ask about the kind of priming that this is likely to reflect. Returning to the QAR for a moment, a first possibility, at least in principle, would be a form of pragmatic priming. However, given the mechanics of the QAR, it is extremely difficult to see how this would work. For example, consider the possibility that the QUD itself is what is being primed. Since ES contexts must give rise to a QUD addressed by the non-isomorphic interpretation on this view (because children behave in a more adult-like fashion in ES), then perhaps some underspecified version of this QUD common to all ES contexts is primed and then carried over to EF contexts, e.g., "Did all of the X do Y?" However, it seems to us that this line of reasoning would defeat the whole point of the QAR, since one would now be forced to conclude that the QUD is not determined by the narrow context in which the test sentence is uttered (and which the test sentence describes). In addition, as discussed earlier, Hulsey et al. (2004) and Gualmini et al. (2008) do not explain precisely how a particular context gives rise to a particular QUD, making it difficult to determine the mechanics of this kind of hypothetical pragmatic priming. For these reasons, we find pragmatic priming to be an unlikely explanation of the priming effect in Experiment 2.

In comparison, structural priming seems more plausible (Bock 1986; Branigan et al. 1995; Hartsuiker, Pickering, & Veltkamp 2004). One possibility is that what gets primed is the logico-syntactic representation associated with the non-isomorphic interpretation of sentences like *Every horse didn't jump over the fence*. On this view, the fact that children access the non-isomorphic interpretation—and thus the relevant logical form (LF) representation—more often in ES contexts should increase the likelihood that this interpretation will be accessed again in subsequent EF contexts. This form of priming would work because the sentences in ES and EF contexts are essentially the same in that they are ambiguous and allow both an isomorphic ('none') reading and a non-isomorphic ('not all') reading. A related idea is that what gets primed here is the scope relation between negation and the QNP (i.e., 'not > every'), or, alternatively, the truth conditions associated with this particular scope relation. If so, notice that the way to ensure that a particular scope relation is met, or that specific truth conditions are satisfied, is to select the appropriate logico-syntactic representation (in this case the one corresponding to the non-isomorphic interpretation). Thus, it seems that whatever ends up

getting primed, the relevant LF representation must be accessed and engaged,¹¹ underscoring the fact that 4-year-olds (i) possess the relevant abstract representations, and (ii) are able to access these representations dynamically in the course of language comprehension.

Summing up, we've concluded that the priming effect observed in Experiment 2 is likely to be syntactic in nature, or perhaps even semantic, rather than pragmatic. By that we mean that what gets primed likely involves abstract syntactic representations (e.g., a particular LF representation or a specific scope configuration between two quantificational elements). In our next experiment, we further explore the kind of priming uncovered in Experiment 2 and remove pragmatics from the equation to the extent possible, thereby providing unequivocal evidence that the "pragmatics only" account cannot be the whole story.

3.3. Experiment 3: Truth Conditions Training

In order to refine our understanding of the kind of comprehension-to-comprehension priming uncovered in Experiment 2, we ask here whether we can prime the non-isomorphic interpretation of ambiguous sentences like *Every horse didn't jump over the fence* by using *unambiguous* sentences that have the same truth conditions as the non-isomorphic interpretation, i.e., sentences like *Not every horse jumped over the fence*. Moreover, to remove any influence of story type, both types of sentences are presented in EF contexts.

3.3.1. Participants

We tested 24 English-speaking children between the ages of 4;00 and 4;11 (15 boys, 9 girls, mean age = 4;06, $SD = 3.8$ mo.). Data from 7 additional children were excluded due to excessive failure on control stories ($n = 6$) or inattention ($n = 1$).

3.3.2. Materials and Procedure

The basic design is essentially the same as the one described for Experiment 2. That is, participants were randomly assigned to one of two conditions: the priming condition or the baseline condition. In each condition, participants were asked to judge a total of 6 test sentences and 5 control sentences. As before, sentence order was counterbalanced across subjects. Control sentences were identical to those used in Experiments 1–2. In the priming condition, the first 3 test sentences were unambiguous sentences (12a), and the last 3 were ambiguous sentences (12b). In the baseline condition, all 6 target sentences were ambiguous sentences (12b).

- (12) a. Not every horse jumped over the pig
 b. Every horse didn't jump over the pig

Crucially, all test sentences in both conditions were presented in EF contexts (Figure 6). In other words, regardless of whether a given story was to be described by a "Not every N" test sentence or an "Every N didn't" test sentence in either condition, its plot invariably involved

¹¹To claim otherwise would be to embrace a theory of scopal ambiguity that dispenses with logical form representations entirely. Such theories have been proposed (e.g., Hornstein 1995; Steedman 2000), but we feel the evidence available does not favor them. See Kennedy (1997) for relevant discussion.

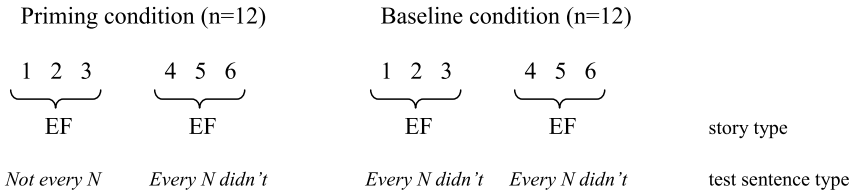


FIGURE 6 Experimental conditions in Experiment 3.

three characters all deciding not to do one task and then only two of the three succeeding at a second task. This design ensured that any observed improvement in children’s access to the non-isomorphic interpretation of our “Every N didn’t” test sentences over the last three trials could be attributed solely to the effect of experience with “Not every N” test sentences as descriptions of the very same story type in the first three trials. For a representative EF story, refer back to (11).

Finally, notice that unambiguous test sentences like (12a) have the same truth conditions as the non-isomorphic interpretation of ambiguous test sentences like (12b). However, the syntactic position of negation differs in these two sentence types,¹² and presumably the abstract logical representations that have been argued to underlie the ‘not every’ meaning that (12a-b) share are distinct. Here again the predictions are that priming, if it were to occur, would manifest itself as a difference in acceptance rates of the non-isomorphic interpretation for sentences like (12b) in the last three test sentences of the priming condition, compared to the last three test sentences of the baseline condition.

3.3.3. Results

Children’s percentage acceptance of test sentences, all of which were true on the non-isomorphic interpretation only, is shown for both conditions in Figure 7.

We found a significant difference between conditions in children’s mean acceptance rates for the last 3 test sentences ($t(22) = 2.9, p = .0083$).¹³ Children’s justifications for their acceptances and rejections of the puppet’s statements were similar to those described for Experiments 1–2. On control items children responded correctly 97% of the time in the priming and baseline conditions.

3.3.4. Discussion

The results of Experiment 3 show that children improve dramatically in their ability to access the non-isomorphic reading of ambiguous test sentences after being primed with unambiguous sentences that have the same truth conditions—even in pragmatically unsupportive EF contexts. There were no explicit contrasts in our test sentences or expectation-inducing story types to which we could attribute this improvement, and the truth conditions training that did occur over the first three trials was systematically absent over the last three trials when the dependent measure was collected. Without a mechanism enabling the persistence of the ‘not every’

¹²*Not* is part of a complex determiner in (12a) but serves as sentential negation in (12b).

¹³Again, logistic regressions yielded the same findings as the *t*-tests.

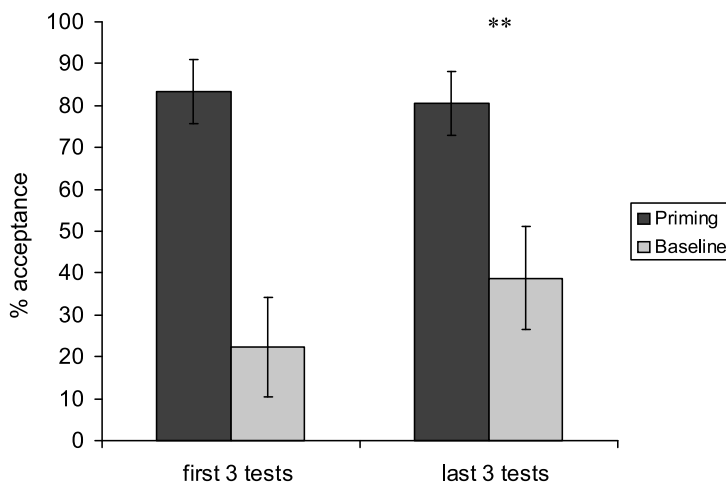


FIGURE 7 Percentage acceptance for test sentences in Experiment 3.

meaning in the absence of contextual support, it seems clear that any account appealing to pragmatic factors alone will not explain the data.¹⁴ Thus, the results of Experiment 3 complement those of Experiment 2, providing converging evidence that such pragmatic factors are insufficient *by themselves* to explain children's non-isomorphism in their interpretations of our test sentences. To reiterate, the language processing system must be implicated in the reduction or outright elimination of the Isomorphism Effect. Both types of training tested in Experiments 2–3 (e.g., story type and truth conditions) led to what can best be described as a change in the balance of power between competing interpretations of ambiguous sentences containing QNPs.

4. GENERAL DISCUSSION

A number of conclusions follow from the results presented here. Consider first the causal question: What factors contribute to observations of isomorphism in preschoolers? As noted in the introduction, a purely grammatical account whereby children lack the syntactic resources to derive nonisomorphic interpretations is untenable (Musolino 2000, 2006b; Gualmini 2004; Musolino & Lidz 2006). The experimentation just presented indicates that although pragmatic considerations certainly play a role in causing isomorphic behavior, these considerations cannot be solely responsible. The priming effects observed in Experiments 2 and 3 demonstrate that aspects of ambiguity resolution attributable to the mechanics of the sentence processor must also be involved in the explanation of isomorphism.

¹⁴An anonymous reviewer correctly points out that we cannot claim to have removed pragmatics from the equation *entirely* in Experiment 3 since the use of "Not every N" sentences themselves could conceivably have prompted certain expectations or implicit QUDs. How such expectations might persist and exert their influence independent of context, as observed, without engaging the language processing system remains unclear.

On this point, Gualmini (2008) offers skeptical remarks regarding the implications of our results, some of which were mentioned by Lidz and Musolino (2005/2006). To quote Gualmini (2008):

“According to Lidz and Musolino (2005/2006), these findings suggest that discourse properties alone cannot explain children’s behavior. We should accept this conclusion with caution. In essence, Lidz and Musolino (2005/2006) are attempting to adjudicate between different theories of scope resolution, something we don’t fully understand, by means of a phenomenon we understand even less. The results documented by Viau, Lidz, and Musolino (2005) demonstrate that inverse scope interpretations can be primed. To understand how this bears on the issue, we need to ask what primes inverse scope interpretations in the study by Viau, Lidz, and Musolino (2005). The answer is quite simple: we don’t know. We do know that syntactic scope is *not* a possible candidate, since there is no verbal prime. In fact, in absence of an explicit theory of priming, we can’t exclude the possibility that the context primes the relevant question, and, in turn, this is used to disambiguate the target sentence. In short, the objections raised by Lidz and Musolino (2005/2006) miss the mark and do not offer us any good reason why we should abandon the Question-Answer requirement for scope assignment proposed by Hulsey et al. (2004)” (1172).

Let us begin with the last sentence in that quote and clarify what we take to be an important misconstrual of our ideas. Our results are not intended to disprove the QAR, or even to argue against the relevance of the QAR (or a similar pragmatic mechanism) as one contributing factor in an explanation of children’s isomorphic behavior. In fact, as far as we are concerned, the QAR may very well be on the right track. Indeed, recall that Hulsey et al. (2004), Musolino & Lidz (2006), and Gualmini et al. (2008) all recognize the fact that pragmatic factors must play a role in the explanation of isomorphism. However, Gualmini et al. (2008) take this conclusion one step further and argue that no factors other than the ones described by the QAR are needed to explain isomorphism. It is this latter conclusion that we take issue with. Rather than disproving the QAR, our results are intended to show that the QAR cannot explain children’s isomorphic behavior *by itself*. In other words, the language processor must be implicated in the explanation of isomorphism above and beyond the role played by context, as shown by the results of Experiment 2, and even more dramatically by those of Experiment 3.

To be fair, the remarks contained in the above quote seem to pertain only to the results of Experiment 2, as suggested by the following statement: “We do know that syntactic scope is *not* a possible candidate, since there is no verbal prime.” The lack of a verbal prime, by which we assume Gualmini means a shared lexical item across the prime and the target, is beside the point. In the syntactic priming literature, there is ample evidence of priming of a structural configuration independent of the lexical items in that structure (e.g., Mehler & Carey 1967; Carey, Mehler & Bever 1970; Bock & Loebell 1990; Cuetos et al. 1996; Trueswell & Kim 1998; Corley & Scheepers 2002; Pickering & Traxler 2004; Branigan, Pickering & McLean 2005), though priming is stronger across sentences with lexical overlap than across sentences lacking such overlap (Cleland & Pickering 2003). More to the point, though, we emphasize the claim made earlier that even if what gets primed in our Experiment 2 is the scope relation between negation and the QNP (i.e., ‘not > every’)—or, alternatively, the truth conditions associated with this particular scope relation—the LF representation subserving and encoding that relation must still be accessed and engaged. One might think of this as a sort of “trickle-down” syntactic priming effect, whereby activation of the ‘not every’ meaning leads

to increased activation of the particular LF representation associated with that meaning of the critical ambiguous sentence. The results of our Experiment 3 can be understood in this light as well, the only difference being that the not every meaning would be primed by an LF representation (for *Not every N* test sentences) that is distinct from the one subsequently activated downstream (in interpreting the non-isomorphic interpretation of *Every N didn't* test sentences).¹⁵

Finally, while it is true that there are competing models of syntactic and semantic priming (see Branigan 2007), uncertainty about the mechanisms responsible for priming does not imply that no conclusions whatsoever can be drawn on the basis of our results, especially since every parsing theory on the market has a mechanism for handling priming effects. In race-based models of ambiguity resolution (e.g., Frazier & Fodor 1978; Ferreira & Clifton 1986), priming would involve increasing the baseline probability of the dispreferred representation so that it is more likely to be chosen after having been recently utilized (Scheepers 2003). In models in which ambiguity resolution involves selection from multiple alternatives generated in initial stages of parsing (e.g., Crain & Steedman 1985; Tanenhaus & Trueswell 1995; Boland & Cutler 1996), priming would involve a shift in the weights assigned to factors that drive selection. Indeed, priming is such a pervasive phenomenon that every parsing theory must have a mechanism for implementing it. To the extent that priming happens in the domain of scope ambiguity resolution, it would be surprising to find any parsing theory that couldn't accommodate it. Thus, while it is certainly an important research goal for the future to identify the precise mechanics of scope priming (cf. Conroy 2008, ch. 3), the fact that these mechanics have not yet been worked out can hardly be taken as an argument against recognizing the relevance of the phenomenon.

In sum, to the extent that non-isomorphic interpretations can be primed, it follows that the causes of isomorphism include the mechanics of ambiguity resolution in the language processor and cannot reduce to purely pragmatic/contextual considerations.

Next consider the developmental question: what factors are responsible for driving the change from the isomorphic behavior exhibited by preschoolers in certain experiments to the more flexible behavior exhibited by adults in the same experiments? Our priming effects raise the possibility that experience with the relevant meanings may play a significant role. The results of Experiments 2–3 reveal that the difficulty that children face in accessing the 'not every' interpretation of scopally ambiguous sentences like *Every horse didn't jump over the fence* can be alleviated by two kinds of prior experience. Prior experience with identical sentences in contexts that promote (for children) the 'not every' interpretation can improve access to that interpretation. Perhaps more surprisingly, even prior experience with different structures involving the same quantifiers can promote access to the 'not every' interpretation. This sort of flexibility would serve the child learner well, especially given the paucity of "Every N didn't" sentences in the input (Gennari & Macdonald 2005/2006).

The last result in particular highlights the importance of an independent level of semantic analysis in determining the likelihood that a given interpretation will be accessed. Because the syntactic structure of the primes in Experiment 3 (e.g., *Not every horse jumped over the pig*) is distinct from the syntactic structure of the targets (e.g., *Every horse didn't jump over the*

¹⁵See German (2007) for a similar proposal with respect to the interpretation of a different class of ambiguous expressions.

pig), it follows that the kind of facilitation we observe here is driven by something outside of the syntax proper. In essence, we have seen that elevating the background probability of an interpretation (by whatever means) makes that interpretation more likely for subsequent sentences.

This perspective on priming also provides a perspective on development. To the extent that the effects of priming are long-lasting,¹⁶ priming and learning can both be understood as a process of shifting the probabilities of certain sentence-meaning pairs. However, it is important to recognize that this approach to learning only makes sense to the extent that the child's grammar already includes resources for generating all meanings for a given sentence. It remains an open question how the initial determination of the range of sentence-meaning pairs is accomplished by the learner. Nonetheless, having shown that experience can play a facilitative role in increasing access to representations that are already part of the child's grammatical repertoire makes it possible for future research to ask what role experience plays in grammatical development more generally.

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¹⁶Initial results indicate that priming lasts at least 3 days and possibly as long as a month.

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APPENDIX A
Stimuli

Experiment 1

Contrast test sentences

Every girl caught a snake, but every girl didn't catch a starfish
 Every spider hid behind the tree, but every spider didn't hide behind the fence
 Every lizard flew over the tower, but every lizard didn't fly over the barn
 Every horse jumped over the cow, but every horse didn't jump over the pig
 Every frog jumped in the water, but every frog didn't jump in the mud
 Every butterfly went to the forest, but every butterfly didn't go to the city

No-contrast test sentences

Every girl didn't catch a starfish
 Every spider didn't hide behind the fence
 Every lizard didn't fly over the barn
 Every horse didn't jump over the pig
 Every frog didn't jump in the mud
 Every butterfly didn't go to the city

Control sentences

The beetles [didn't look in the cave (T)/didn't look in the tree (F)]
 The dinosaurs [didn't draw pictures (T)/didn't sing "Happy Birthday" (F)]
 Every whale [played with a ball (T)/swam home for dinner (F)]
 Every sheep [found a penny (T)/bought candy (F)]
 Every boy [put on a hat (T)/looked in the mirror (F)]

Experiment 2

Test sentences (Priming and Baseline)

Every girl didn't catch a starfish
 Every spider didn't hide behind the fence
 Every lizard didn't fly over the barn
 Every horse didn't jump over the pig
 Every frog didn't jump in the mud
 Every butterfly didn't go to the city

Control sentences (same as in Experiment 1)

The beetles [didn't look in the cave (T)/didn't look in the tree (F)]
 The dinosaurs [didn't draw pictures (T)/didn't sing "Happy Birthday" (F)]
 Every whale [played with a ball (T)/swam home for dinner (F)]
 Every sheep [found a penny (T)/bought candy (F)]
 Every boy [put on a hat (T)/looked in the mirror (F)]

Experiment 3

Priming test sentences

Not every girl caught a starfish
 Not every spider hid behind the fence
 Not every lizard flew over the barn
 Not every horse jumped over the pig
 Not every frog jumped in the mud
 Not every butterfly went to the city

Baseline

Every girl didn't catch a starfish
 Every spider didn't hide behind the fence
 Every lizard didn't fly over the barn
 Every horse didn't jump over the pig
 Every frog didn't jump in the mud
 Every butterfly didn't go to the city

Control sentences (same as in Experiments 1–2)

The beetles [didn't look in the cave (T)/didn't look in the tree (F)]
 The dinosaurs [didn't draw pictures (T)/didn't sing "Happy Birthday" (F)]
 Every whale [played with a ball (T)/swam home for dinner (F)]
 Every sheep [found a penny (T)/bought candy (F)]
 Every boy [put on a hat (T)/looked in the mirror (F)]
