Empirical and theoretical evidence for a model of quantifier production

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Abstract

In this chapter we discuss an account of quantifier usage in terms of multiple constraint satisfaction. This model proposes a set of constraints governing the speaker's choice of quantified expressions, which are individually motivated by appeal to the experimental literature. By situating these constraints within an Optimality Theory framework, we can draw testable predictions about quantifier usage. Furthermore, assuming that hearers interpret these utterances rationally, it follows that interpretations are also governed by the proposed constraints. We review recent experimental data that validates some predictions of this model. Then we consider its extension to non-numerical quantification, with particular reference to the much-discussed case of scope readings in negatively quantified sentences, and consider how it bears upon the analysis of the critical data. We present new experimental data that test the model's applicability to this domain and discuss its implications.

1. Introduction

Since Montague (1970), attempts have been made to capture the semantics of natural language expressions using the formalisms of logic, with varying degrees of success. One area to yield good progress in this regard has been quantification. Quantifiers such as "some" and "all" and numerically-quantified expressions such as "more than *n*" appear especially amenable to this type of formalisation. Indeed, it would seem that most natural language expressions of this kind can be recast as statements about the cardinalities of various sets. (1), (2) and (3) exemplify this approach for the case of a numeral, "some" and "most" respectively.

(1) There are two Xs.
|[X]| = 2

(2) Some of the Xs are Ys.
$|[X] \cap [Y]| \neq 0$

(3) Most of the Xs are Ys.
$|[X] \cap [Y]| > |[X] \setminus [Y]|$

As observed by Geurts et al. (2010: 131), analyses of this type are prevalent in linguistics (Barwise and Cooper 1981), psycholinguistics and the psychology of reasoning (Smith 1980, Evans, Newstead and Byrne 1993). However, in recent years, a series of semantic accounts of specific quantifying expressions have dissented from the obvious and argued for alternative semantic accounts. A prominent debate in the literature has concerned the core semantics of numerals (Carston 1998, Geurts 2006, Breheny 2008 i.a.), and specifically whether they are to be considered precise, lower-bounding or underspecified. However, theorists have also noted that the apparently obvious formalisms are inadequate as an account of the meaning of other expressions: "at least/most" (Geurts and Nouwen 2007), "most" versus "more than half" (Hackl 2009, Solt 2010), "no more/fewer than" (Nouwen 2010) among others.

An alternative to reformulating the semantics of such expressions is to acknowledge the prevalence of additional aspects of meaning that are not captured by the traditional semantics, but to argue that these are generated by pragmatic considerations. One proposal of this kind is offered by Cummins and Katsos (2010), which presents experimental evidence that "at least/most" is more complex than "more/fewer than" and argues that the use of the former gives rise to certain implicatures.

In this chapter, we explore a more general account along similar lines, the constraint-based model of quantifier usage proposed by Cummins (submitted). We summarize the architecture of this model and list the constraints that it posits, touching upon the evidence for their functional motivation. We briefly discuss some of the novel predictions this model makes about usage and interpretation in the numerical domain and their empirical verification. Then we consider a novel application of this model addressing a further issue connected with quantifier usage, namely the apparent preference for isomorphic interpretations (Musolino, Crain and Thornton 2000). We draw predictions from this model and subject them to experimental validation, both in production and in comprehension. We conclude by discussing the relation of this model to the approaches adopted in the existing literature on isomorphism.

2. Outline of a constraint-based model of numerical quantifier usage

The model of numerical quantifier usage proposed by Cummins (submitted) uses a system of multiple constraint satisfaction within an Optimality Theory (OT) framework (Prince and Smolensky 1993). Unlike prior applications of OT to pragmatics (Hendriks and de Hoop 2001, Blutner 2006) this uses a unidirectional speaker-referring model, and is thus designed to model the speaker's process of utterance selection under the relevant contextual conditions. The input layer represents the situation in this model, and the output layer represents the utterance.

In common with classical OT models, this approach postulates a system of three components: CON, a ranked set of constraints, GEN, which generates candidate outputs, and EVAL, which evaluates the candidates against the constraint set. The system selects the optimal candidate by looping through the constraints in descending rank order and discarding candidates that incur violations, until an optimal candidate remains. Given a set of constraints that are individually functionally motivated, it can be argued that such a system has the potential to constitute a psychologically plausible account of speaker behaviour.

Cummins (submitted) proposes six constraints and argues for them on a combination of empirical, theoretical and philosophical grounds. The first constraint, informativeness, requires that the utterance be informative in the sense of excluding the maximal number of possibilities that the speaker can: if the speaker knows that "more than 11" holds, "more than 10" would incur one violation of this constraint. The second constraint, granularity, requires that the utterance conveys information at the appropriate (numerical) granularity level. Relatedly, a constraint on numeral salience requires that a salient (round) numeral be used, on the grounds that such numerals have been shown to be privileged psychologically and can thus be used with less cognitive effort on the part of both speaker and hearer. A further constraint, numeral priming, requires the re-use of contextually activated numerals, again on the grounds that these are predicted to be available to speaker and hearer at lower cognitive costs. Finally, two constraints are proposed to govern the non-numerical portion of the quantifier: a simplicity constraint, requiring the use of a simple quantifier (the bare numeral, i.e. the absence of a non-numerical quantifier, presumed to be the simplest) and a priming constraint, requiring the re-use of a contextually activated quantifier, if one is present.

Although this model supposes that speakers differ in their constraint rankings, it enables general predictions to be made about trends in usage. Some of these trends are predicted to arise on account of the "emergence of the unmarked" (McCarthy 2002: 129) – the tendency, in an OT system, for markedness constraints to exert an effect in determining the optimal outputs even when they are lowly-ranked. In this model, the markedness constraints are those on numeral salience and quantifier simplicity. However, the existence of the faithfulness constraints also predicts that speaker behaviour will differ in cases where these are violable – for instance, in the case of the priming constraints, when a numeral or quantifier is mentioned in the preceding discourse.

Moreover, on the assumption that hearers are pragmatically astute and can use distributional information about utterances in order to compute enrichments to their meaning, this model also enables the framing of predictions about the interpretation of utterances. The hearer is privy to two types of information: the optimal utterance, given the situation and the speaker's constraint ranking (under the assumptions of this model, the speaker's utterance is optimal); and contextual information, including the content of the preceding discourse. From this, the hearer aims to recover the speaker's intention. The hearer is predicted to be able to use his or her implicit knowledge of the linguistic system (including what constitutes a complex quantifier or a non-salient numeral), along with knowledge about the context, to recapture the speaker's meaning from the choice of utterance. This represents a natural generalisation of the abductive reasoning that hearers are customarily assumed to undertake in order to compute pragmatic enrichments (Geurts 2010: 34). Practical examples of the postulated reasoning process will be given in the following section.

In recent work this model has been used to draw out predictions about numerical quantifier usage and interpretation, which have been empirically tested (Cummins, Sauerland and Solt submitted). In particular, by appeal to the number-referring constraints in the system, considerations from the psychology of number are productively brought to bear on problems connected with the linguistic pragmatics of quantity expressions. In the following section, we briefly review some of these findings. In the remainder of the chapter, we turn our focus to the non-numerical constraints and consider how these give rise to predictions about the behaviour of quantifiers in general.

3. Drawing and testing predictions about numerical quantifier usage and interpretation

By appeal to the model discussed above, various predictions can be made about the usage of numerically-quantified expressions. These can then be adapted into predictions about the interpretation of these expressions. Here we briefly review how this approach accounts for three facets of the meaning of numerically-quantified expressions: the apparent modality of superlative quantifiers, implicatures arising from comparative quantifiers, and the approximative use of unmodified round numbers.

Turning first to superlative quantifiers (those of the form "at least *n*" and "at most *n*"), Geurts and Nouwen (2007) demonstrate the inadequacy of the classical account by showing that these expressions behave unlike the corresponding comparative quantifiers ("more than *n*-1" and "fewer than *n*+1" respectively, in cardinal contexts). Superlative quantifiers fail to give rise to entailments that are predicted to be valid from a logical perspective ("at most *n*" typically fails to entail "at most *n*+1") and the two classes of quantifier differ in their distributional patterns.

Geurts and Nouwen (2007) account for this by positing that superlative quantifiers possess a modal component of meaning – "at least/most *n*" are argued to encode the certainty that "fewer than *n*" does not hold and the possibility that "more than *n*" holds. However, Cummins and Katsos (2010) show that this component of meaning fails to surface in certain contexts, and propose that it arises as a pragmatic enrichment. Specifically, they show that non-strict comparison (such as is expressed by superlative quantifiers) is more demanding to process than is strict comparison (such as is expressed by comparative quantifiers). They propose that this complexity arises because non-strict comparison is represented disjunctively at the psychological level ("at least" = "greater than or equal to"), and thus its declarative use gives rise to an implicature that either disjunct might hold.

Within the constraint-based model, this observation can be captured in a more parsimonious way. According to this approach, "more than *n*-1" is preferred to "at least *n*" on the grounds that it uses a less complex quantifier, and thus violates the quantifier simplicity constraint to a lesser extent, except when *n* is a salient numeral. In this case, "more than *n*" is preferred to "at least *n*" when the former is known to be true, and thus the use of "at least *n*" implicates that this condition is not met and therefore "exactly *n*" is considered to be a possibility. This account fits with the observations of Geurts and Nouwen (2007) and the empirical data gathered by Geurts et al. (2010) and Cummins and Katsos (2010), while avoiding the

stipulation that the meaning of superlative quantifiers is necessarily disjunctive.

A second application of the constraint-based model concerns pragmatic enrichments arising from comparative quantifiers. "More than *n*" and "fewer than *n*" have been argued not to give rise to scalar implicatures (Fox and Hackl 2006; developing a claim of Krifka 1999,, that superlative quantifiers do not do so). They observe that, for instance, (4) fails to implicate (5), as otherwise (4) and (5) together would entail (6), whereas participants uniformly reject the idea that (4) can be interpreted as (6). However, although it is argued on the basis of such examples that comparative quantifiers fail to participate in Horn scales (Horn 1984), no clear explanation is provided as to why.

(4) John has more than three children.

(5) John does not have more than four children.

(6) John has exactly four children.

From the constraint-based perspective, it can be argued instead that such examples are the exception rather than the rule, and depend upon the proximity of adjacent scale points where small numbers are concerned. On the basis of considerations of numeral salience and informativeness, "more than *n*" is predicted to implicate "not more than *m*" (under the usual assumptions as to the speaker's epistemic commitments) where *m* is the next numeral above *n* which is at least as salient. Therefore, comparative quantifiers are predicted to implicate a pragmatic bound – for instance, (7) should implicate (8) – and the strength of the bound should relate to the roundness of the numeral.

(7) More than 300 people attended.

(8) Not more than 400 people attended.

Cummins, Sauerland and Solt (submitted) test this prediction experimentally and show that pragmatic bounds of this type are elicited by the use of comparative quantifiers, conditioned by numeral roundness, and that at least some participants are consciously aware of the reasoning process that underlies that enrichment.

Considering the numeral priming constraint in addition to numeral salience and informativeness, the model gives rise to the further prediction that the prior mention of the numeral will attenuate the implicature – that is, the use of a comparative quantifier in this context will give rise to more distant pragmatic bounds. This is also verified by Cummins, Sauerland and Solt (submitted).

Moreover, by appeal to the numeral priming constraint, it may be possible to account for the systematic failure of implicature in cases such as those discussed by Fox and Hackl (2006). Given the possibility of implicature, (4) would convey (6), raising the question of why (6) would not simply have been uttered in its stead. However, according to the constraint-based account, (4) might be preferred if it satisfies numeral salience – that is, if "three" is a contextually salient number. In this case, the implicature fails, on the basis that more informative utterances would fail to satisfy numeral salience and are therefore dispreferred. Consequently, the model predicts that utterances such as (4) can surface when (and only when) the numeral is primed. If this prediction is borne out in actual usage, the model serves to explain the absence of implicatures from utterances of this type without any stipulation as to the inability of these structures to enter into Horn scales.

Finally, this approach provides an account of the approximative use of round numbers that resembles that of Krifka (2009). If we suppose that round and non-round numbers are both semantically able to convey approximate meanings, then they are in principle able to compete as potential expressions of both round and non-round meanings. A speaker who wishes to convey the meaning "(exactly) 51" could then do so in a semantically appropriate way by using either "50" or "51". In this case, "51" would be preferred on the grounds of informativeness, or potentially granularity, but "50" would be preferred with respect to numeral salience. Therefore, which one is used is predicted to depend upon the speaker's constraint ranking. By contrast, if we consider the meaning "(exactly) 50", then once again "50" and "51" compete (among other options), but "50" harmonically bounds "51", as it is preferred with respect to all relevant considerations. Generalising across cases, then, non-round meanings can be expressed both by round and non-round numbers, while round meanings can be expressed only by round numbers. It follows that round numbers are capable of conveying a range of meanings, while non-round numbers are not. Thus, the generalisation about the approximative usage of round numbers is recovered.

In summary, then, the constraint-based model gives an economical account of observable patterns of usage and interpretation for several classes of numerically-quantified expression. In what follows, we develop this line of research further by applying it to an instance of non-numerical quantification, appealing to the quantifier simplicity and quantifier priming constraints.

4. Non-numerical quantification: the case of isomorphism

Complex quantificational expressions have long been noted to give rise to potential scope ambiguities (Jackendoff 1972, i.a.). In particular, expressions involving negation have been widely discussed in the semantics and pragmatics literature. Sentences such as (9) and (10) are argued to admit two distinct interpretations:

(9) All of the toys are not in the boxes.
(10) Some of the toys are not in the boxes.

On the first reading, (9) states that all the toys have the property of not being in the boxes, i.e. that none of them are in the boxes. On the second, it states that it is not the case that all the toys are in the boxes. This latter interpretation is compatible with a situation where some but not all of the toys are in the boxes. Similarly, (10) can be interpreted either as stating that some of the toys have the property of not being in the boxes, which is compatible with a situation in which some but not all of the toys are in the boxes; or as stating that it is not the case that some of the toys are in the boxes, i.e. that none of them are in the boxes.

These readings differ with respect to the scope of negation. In the first case, if 'all' takes scope over 'not', we obtain the "none" of the toys are in the boxes reading, whereas if 'not' takes scope over 'all', we obtain the "possibly some but not all" reading. In the second case, if 'some' takes scope over 'not', we obtain the "possibly some but not all" reading, whereas if 'not' takes scope over 'some', we obtain the "none" reading. In each case, the former reading is that in which the semantic relations match the syntactic relations, assuming that 'all' c-commands 'not' in (9) and 'some' c-commands 'not' in (10). This is referred to by Musolino, Crain and Thornton (2000) as the *isomorphic* interpretation. The reading in which the semantic relations do not match the syntactic relations (that is,

where negation takes scope over the quantifier) is referred to as the non-isomorphic interpretation.

While both interpretations of quantified sentences are accessible to competent speakers, previous research has attempted to ascertain which is privileged in communication. The question is whether one of the two mappings from syntactic form to semantic structure is more fundamental to child language acquisition and/or adult sentence processing, and if so, which and why. This issue is particularly relevant to linguists working within a cognitive psychology framework, the eventual goal of which is to explore how linguistic knowledge is acquired, represented and used in the minds of interlocutors.

4.1. Current theories of isomorphism

A substantial body of research supports the observation of isomorphism across a range of expressions and test conditions. Consequently, the debate in the literature has homed in on the question of whether this preference reflects a cognitive bias of some kind on the part of the individual, or whether it is due to contextual considerations (and if so, which). Here we briefly summarize the major findings in this research tradition and discuss the theoretical positions adopted.

Musolino, Crain and Thornton (2000) demonstrated that although adults were able to access both the isomorphic and the non-isomorphic readings of sentences with 'every' + negation, English-speaking children generally exhibited access only to the isomorphic reading. To do so, they used test sentences of the form "Every N didn't VP", presented in the context of stories involving three characters and two actions to be performed. Each of the characters failed to perform the first action, and then two of the characters performed the second action, while the third did not. With respect to the second action, "Every N didn't VP" was false on an isomorphic reading ("it is the case that, for every N, that N did not VP") but true on a non-isomorphic reading ("it is not the case that every N did VP"). Their adult controls accepted these descriptions in 100% of cases, suggesting that they had accessed the non-isomorphic reading, whereas the child group (20 individuals aged from 4;0 to 7;3, mean 5;11) accepted these descriptions in only 7.5% of cases, suggesting that they overwhelmingly accessed the isomorphic reading. In a follow-up experiment, they excluded the possibility that children were unable to assign negation scope over "every". Instead, they argued that there is a stage in language development

where child grammar is restricted to the semantic scope assignments that coincide with the surface syntactic scope. They observed a parallel with languages in which isomorphic readings are obligatory, such as Chinese, and suggested that the difference between obligatory isomorphism and optionality could reflect the setting of a UG parameter.

Lidz and Musolino (2002) further developed this research in two ways. First, they showed that the observation of isomorphism held for numerically-quantified expressions such as "Donald didn't find two guys" as well. Secondly, they demonstrated that isomorphism held with respect to the syntactic relation of c-command rather than surface linear order, by studying speakers of Kannada, a Dravidian language in which the relevant c-command relationships were not expressed in linear order.

Gualmini (2004) disputes the claim that the non-isomorphic reading is unavailable in child grammar. He discusses the role of context in licensing the use of negative sentences in general, and proposes that the lack of non-isomorphic interpretations can be attributed to the felicity conditions applying to the test items. In particular, he investigates the interpretations of sentences such as (11) and (12) by 4-5 year old children, in the context of a story in which the Troll is supposed to deliver four pizzas but loses two on the way.

(11) The Troll didn't deliver some pizzas.
(12) The Troll didn't lose some pizzas.

Both these utterances are false on their isomorphic reading and true on their non-isomorphic reading: under the former, these state that it is not the case that the Troll delivered/lost some pizzas (false), while under the latter they state that there exist some pizzas that the Troll didn't deliver/lose (true). However, Gualmini (2004) further proposes that, in order to be felicitous, negated utterances of this type must serve to point out the discrepancy between what was expected to happen (in this case, that the Troll should deliver all the pizzas) and what actually happened. Thus, (11) is felicitous on its non-isomorphic reading, because it points out that the expected occurrence did not take place. (12) however is not felicitous on the non-isomorphic reading, because it does not point out any relevant discrepancy, as no pizzas were expected to be lost. Gualmini found that a group of children aged 4;1 to 5;6 accepted (11) and similar forms 90% of the time, while a different group aged 4;2 to 5;8 accepted (12) and similar forms only 50% of the time. He concludes that the interpretations children achieve are governed by discourse considerations, and suggests that

children and adults differ in their ability to accommodate pragmatic infelicity with respect to the discourse conditions that license negated statements.

Musolino and Lidz (2006) also obtain data that casts doubt on the contention that the non-isomorphic reading is absent from the child's grammar. They show that children aged 5 can access the non-isomorphic reading in a majority of cases if the negative sentence was preceded by a contrastive affirmative sentence. For example, if the child was presented with a scenario in which all three out of three horses jumped over a log and then two out of the three jumped over a fence, (13) would typically be rejected but (14) would typically be accepted.

(13) Every horse didn't jump over the fence.
(14) Every horse jumped over the log but/and every horse didn't jump over the fence.

Musolino and Lidz (2006: 840ff) argue that this demonstrates the child's grammatical ability to access non-isomorphic readings, contrary to Musolino, Crain and Thornton (2000). These results compel Musolino and Lidz (2006) to abandon the grammatical account, and endorse a view in which context is a relevant consideration, as argued by Gualmini (2004). They posit instead that children are less readily able to access non-isomorphic readings because they are less sensitive to the pragmatic factors that give rise to the adult preference. Adults, for instance, are aware that 'nobody VP' is in competition with 'every person *neg* VP', and thus by Gricean pragmatic considerations the latter attracts a non-isomorphic reading. In particular, Musolino and Lidz consider the possibility that these pragmatic factors are potentially in conflict with syntactic preferences, and that these syntactic preferences tend to 'win out' in the competition as far as children are concerned. They discuss this with reference to the account of Trueswell et al. (1999), in which adults are shown to use pragmatic information to resolve syntactic ambiguities at early stages of processing, while children do not take such information into account and are not able to revise their initial parsing commitments.

Hence, the general view endorsed by Musolino and Lidz (2006) is one in which the default interpretation is the isomorphic one, and this is susceptible to modification under the appropriate contextual conditions. All things being equal, the semantics follows the syntax, as per the observation of isomorphism. However, if context demands it, and if the hearer is able to respond adequately to these contextual considerations, the

preference for isomorphism may be overridden and non-isomorphic interpretations derived. This account is labelled Isomorphism-by-Default by Gualmini et al. (2008).

Developing Gualmini's earlier work, Gualmini et al. (2008) focus on the question of why children who can access the non-isomorphic interpretation nevertheless sometimes select the isomorphic interpretation, even when it makes the sentence false. Their contention is that this can be explained in terms of the Question-Answer Requirement (QAR), a well-known condition which stipulates that "any sentence must be understood as an answer to a question" (2008: 213). Specifically, they claim that "what is special about the 'biased' contexts in which children have been found to show a preference for surface scope is that, in these contexts, only the surface scope interpretation constitutes a good answer to the Question under Discussion" (ibid.). For instance, with regard to the pizza story, Gualmini et al. argue that the Question under Discussion is "Did the Troll deliver all the pizzas?", which is answered satisfactorily (in the negative) by (11) construed non-isomorphically.

In addition to this, Gualmini et al. (2008) present new experimental data, aiming to adjudicate between their QAR-driven proposal and the Isomorphism-by-Default account of Musolino and Lidz (2006), under which non-isomorphic interpretations are available but children cannot exploit the context in such a way as to derive them. In this, they test a modified version of the pizza story, in which children are asked to judge the truth of (15).

(15) Some pizzas were not lost.

Under the Isomorphism-by-Default account, participants are expected consistently to accept this sentence, whereas the QAR proposal predicts that participants will accept it only to the same extent as sentences such as (12). Their results bear out this latter prediction, and adjudicate in favour of the QAR account rather than an Isomorphism-by-Default account.

Hence, Gualmini and colleagues contend that the apparent preference for isomorphic interpretations is an emergent phenomenon, due in fact to the discourse context and nature of the items tested rather than the linguistic competence of the participants. They argue that the QAR accounts parsimoniously for the observed data, and thus renders it "unnecessary to assume a default preference for surface scope interpretations in children or adults" (2008: 225).

However, Conroy, Lidz and Musolino (2009) in turn cast doubt on the validity of the experimental data obtained by Gualmini et al. (2008). In their experiment, they follow Gualmini et al. in using an experimental methodology which has been shown to make non-isomorphic readings available, using a truth-value judgement task on items of the form "Every…didn't". They compare a group of 4-year-olds (mean age 4;9) to a group of 5-year-olds (mean age 5;2) and adult controls. The younger child group accepted non-isomorphic uses of their items in 82% of cases, while the older child group accepted these significantly less often (44%), with 7 of the 15 five-year-olds rejecting these items every time. The adult control group accepted 76% of the non-isomorphic items. For Conroy, Lidz and Musolino, this shows that the availability of non-isomorphic readings exhibits U-shaped development. They argue that the early availability of such readings is an example of "apparent adult-like behavior by non-adult-like means" (p.114).

In summary, the recent literature showcases two competing perspectives. According to Musolino, Lidz and colleagues, both readings are available in the grammar, but there is a strong preference for isomorphism, which is presumed to arise from syntactic and parsing considerations. On this account, children can access the non-isomorphic reading only when they are able to use multiple contextual cues to overcome the bias towards isomorphism. According to the competing account by Gualmini and colleagues, there is no inherent preference for isomorphism and both readings are equally accessible in the grammar. All that matters is which of the two readings is a plausible answer to the question under discussion. The contexts used in experiments have, on this account, typically been implicitly biased towards supporting the isomorphic interpretation. However, given neutral contexts, children should be able to access both readings unproblematically throughout development.

4.2. Isomorphism in the constraint-based model

The constraint-based model under discussion here makes specific predictions about the way context should influence the availability of non-isomorphic readings. Specifically, the quantifier priming constraint predicts the re-use of quantifiers in potentially non-isomorphic contexts. Consider (13) and (14), repeated below, from Musolino and Lidz (2006).

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

(14) Every horse jumped over the log but/and every horse didn't jump over the fence.

The second clause of (14) is identical to (13), but surfaces in the context of the first clause of (14), which is predicted to give rise to priming effects. From the perspective of the constraint-based model, and given the observation of isomorphism (as a generalisation about observable usage), the hearer of (13) might reason that the utterance means (15), on the grounds that a speaker who wished to convey (16) would have said this in so many words.

(15) No horses jumped over the fence.
(16) Not every horse jumped over the fence.

However, on this account, the hearer of (14) might suppose that the choice of second clause reflected the speaker's preference to reuse the quantifier "every" without prior negation, as this has been primed. Consequently, the utterance is compatible with scenarios (15) and (16), and hence the non-isomorphic interpretation is predicted to be available.

Again, the constraint-based account has the potential advantage of enabling us to frame precise predictions as to the influence of context on the availability of non-isomorphic readings that are functionally motivated, and to do this without appeal to additional theoretical machinery. The analysis is founded on the same constraints that are posited for general quantification, under some fairly minimal assumptions as to what constitutes a sufficiently close correspondence to yield priming. Moreover, as discussed earlier, the account makes predictions about preferences in both usage and interpretation, and relates these systematically. In the following subsection, we present novel experimental data which aims to test the usefulness of the constraint-based approach to this problem, while also aiming to distinguish between the predictions of the contextual and default accounts of isomorphism, with respect to both production and comprehension.

4.3. Experiment – production and comprehension of non-isomorphic statements

We used a laptop-based task to assess the comprehension and production of quantified expressions. In this task the experimenter introduces participants

to a fictional cartoon character and explains that they should help the character learn to speak their language better. In this particular game, the cartoon character is a female, the Cavemom, and she is asked "to say how many boxes have a toy". If what she says is right, the participant should tell her "that is right". If what she says is wrong, the participant should tell her "that is wrong", and also tell her why it was wrong, in order to help her learn.

In each trial of the experiment, an array of boxes appears on the screen, along with the corresponding number of instances of an object. The objects are those that young children are familiar with, such as dolls, balls, cars etc. (for a description of the criteria employed for selecting objects see Katsos et al. (2011)). Each instance of an object may be inside or outside the corresponding box (see Appendix for sample items). An audio recording is played, representing the Cavemom's description of the situation. The participant gives a verbal response, which is recorded by the experimenter.

The goal of this design is to capitalize on the importance of context, but steer away from conditions that strongly bias one or the other reading. By considering the results of this experiment across three age groups (7-, 9- and 11-year-olds) and adult controls, we can trace the availability of non-isomorphic expressions from both a comprehension and a production perspective, and thus contribute to understanding the time-course of this development.

The version of the experiment that we administered to children assesses participants' performance on eight quantifiers: 'all', 'all…not', 'none', 'some', 'some…not', 'not all', 'most', and 'half'. For 'all', 'none' and 'half', there are true and false conditions. For 'all…not', 'some', 'some…not', 'not all' and 'most', there are true, false and under-informative conditions. The under-informative condition is one for which the expression is logically true, but there exists an alternative expression that would have been more informative. For instance, in the case of 'some', the utterance is "Some of the boxes have a toy". The condition in which none of the boxes have a toy is false for this description; that in which exactly two of the boxes have a toy is true; that in which all of the boxes have a toy is under-informative.

In this task, we can directly examine participants' ability to derive isomorphic and non-isomorphic interpretations of 'all…not' and 'some…not' by considering whether they accept or reject utterances of this type in the critical conditions, in which none or just some of the boxes have a toy. The scenarios are minimal in this experimental paradigm. The question under discussion, given explicitly in the introduction to the

experiment, is "to say how many boxes have a toy". Given this question, either interpretation of the critical sentences (isomorphic or non-isomorphic) would make the Cavemom's utterance a valid description of the situation.

It should be acknowledged that responses of the type Quantifier + Negation may not be optimally felicitous, as several other expressions such as "none", "some" and "not all" could be used instead. This potential infelicity is manifest in previous research: for example, the items of Gualmini et al. (2008) are of this type, whereas sentences without negation are preferred in production for similar situations (Gennari and McDonald 2006). However, irrespective of whether the utterances are wholly felicitous, the point stands that both isomorphic and non-isomorphic interpretations of these items should be equally successful in answering the question under discussion.

There is also a production component to the task, in which participants are asked to correct the cases where they said that the Cavemom is wrong. In such cases, the participant has the opportunity to produce 'all…not' or 'some…not' forms, intending either the isomorphic or the non-isomorphic interpretation, although of course (s)he is not compelled to use such a form.

In the following section, we will spell out our hypotheses about the levels of acceptance and types of correction produced across the groups under test. We will then evaluate these with respect to the empirical data.

4.3.1. Hypotheses

The participants' first task is to judge whether the utterance offered to describe the situation is true. On the semantic conditions, we expect performance at high levels for all age groups for the simplest quantifier, in accordance with established findings (Noveck 2001), but lower performance for the more complex quantifier "most" (Katsos et al. 2011). On the under-informative conditions, we expect performance to be at neither floor nor ceiling (Katsos and Smith 2010; Katsos and Bishop 2011) and children to accept these at a higher rate than adults on the grounds that their sensitivity to informativeness is less attuned (Noveck 2001: 183).

The critical conditions for isomorphism are "all…not" and "some…not". For these items, whether a description is true, false, or true but under-informative will depend on whether the isomorphic or non-isomorphic interpretation is accessed. This is summarized in Table 1.

Table 1: Semantic and pragmatic status of items given isomorphic and non-isomorphic readings

Utterance	Reading	Situation		
		No items in	Two items in	All items in
"all…not"	Isomorphic	True	False	False
	Non-isomorphic	Under-informative	True	False
"some…not"	Isomorphic	Under-informative	True	False
	Non-isomorphic	True	False	False

The critical question for our purposes is how the rates of acceptance for isomorphic readings compare to those for non-isomorphic readings. According to the Isomorphism-by-Default account (Musolino and colleagues), the former should be preferred across all age groups, with non-isomorphic readings only becoming available as the participants increase in age and are better able to integrate the contextual considerations that would license non-isomorphic interpretations. We assume that the Principle of Charity will apply, which enjoins the comprehender to select the interpretation of a sentence that would render it true in context, as discussed by Musolino and Lidz (2003). Thus, if the non-isomorphic interpretation is required to make a description true, we expect participants capable of accessing this interpretation to do so and accept the description. Similarly, where the isomorphic interpretation is required, we expect participants to access this interpretation. An asymmetry is predicted to arise because all participants can access the isomorphic interpretation, but not all participants can access the non-isomorphic interpretation. Thus the isomorphic conditions are predicted to attract higher acceptance rates than the non-isomorphic conditions.

However, according to the QAR account (Gualmini and colleagues), the interpretation is always context-dependent. Young children should accept non-isomorphic descriptions from an early age, as these answer the QAR just as satisfactorily as isomorphic descriptions. Assuming that the Principle of Charity applies, participants should therefore always accept "all…not" in the two-items case. If it does not, participants should accept "all…not" for the some-items case at chance rates. Similarly, they should accept "some…not" for the no-item case in at least 50% of cases. Because under-informative items might also be accepted, this account also predicts

that “all…not” will be accepted more frequently in the no-item case than the two-items case, as the former could either be due to an isomorphic reading or a non-isomorphic reading with tolerance of under-informativeness, while the latter requires a non-isomorphic reading. However, this account distinctively predicts that “some…not” will be accepted more frequently in the no-item case than in the two-items case, the former again reflecting either a non-isomorphic reading or an isomorphic reading with tolerance of under-informativeness, while the latter requires an isomorphic reading.

Hence, with respect to “all…not”, the Isomorphism-by-Default account predicts that the level of acceptance in the two-item condition will initially be low, and increase with age, the highest level being achieved by the adult group, as this acceptance relies on the participant being able to access the non-isomorphic reading. By contrast, acceptance of “all…not” in the no-item condition will be high from an early age, as this only requires access to the isomorphic reading. With respect to “some…not”, this account predicts that the level of acceptance in the no-item condition will initially be low (accepted only when under-informativeness is tolerated) and increase with age, the highest level again being achieved by the adults. In either case, the rates of non-isomorphic readings will be lower than isomorphic ones, even in the adults. By contrast, the QAR account predicts that “all…not” will be widely accepted in the two-item condition by the young participants, and that “some…not” will be accepted in the no-item condition more frequently than in the two-item condition. The adults should show isomorphic and non-isomorphic interpretations at ceiling rates, depending on whichever renders the utterance true in context.

The constraint-based account does not make distinctive predictions with regard to the interpretations of these utterances, as no quantifier priming is predicted to be in effect. In particular, if we assume the validity of the observation of isomorphism as an empirical generalisation, these contexts are not predicted to license non-isomorphic readings. In this respect the constraint-based account patterns with the Isomorphism-by-Default account as regards comprehension in this experiment.

Turning to the production component of this experiment, we can distinguish the predictions of the existing theories and derive more distinctive predictions from the constraint-based model. If the speaker wishes to correct a sentence uttered by the Cavemom, they are semantically entitled to produce various utterances: for instance, in a no-items scenario, (17), (18) and (19) are potentially valid descriptions, given an isomorphic interpretation for (18) and a non-isomorphic interpretation for (19).

(17) None of the boxes have a toy.
(18) All the boxes don't have a toy.
(19) Some of the boxes don't have a toy.

Generally, there is a robust intuition supported by experimental evidence (Gennari and McDonald 2006) that the simpler expressions are preferred over the structurally complex critical sentences, which are rarely selected. Within the constraint-based model, this is attributable to the action of the quantifier simplicity constraint, although clearly this is not a model-specific prediction. However, the question remains as to whether the complex forms that do arise are selected to convey isomorphic or non-isomorphic meanings.

In our experiment, we expect the items shown in Table 2 to elicit corrections.

Table 2: Items that the participants are predicted to reject and correct

Quantifier	**Situation**	**Grounds for correction**
All	Two items in	False
All…not	Two items in	False (isomorphic reading)
All…not	All items in	False (either reading)
Half	Five items in	Under-informative
Most	All items in	Under-informative
Most	Two/three items in	False
None	Two items in	False
Not all	All items in	False
Not all	No items in	Under-informative
Some	All items in	Under-informative
Some	No items in	False
Some…not	All items in	False (either reading)
Some…not	No items in	Under-informative (isomorphic reading)

Thus, there is potential for "some…not" and "all…not" to be used as corrections, both under the isomorphic and non-isomorphic interpretations. Isomorphically, "some…not" describes the two-item conditions and "all…not" the no-item conditions; non-isomorphically, the reverse is true.

If productions of this type are attested, these could constitute critical evidence in testing between the competing predictions on isomorphism. Under the Isomorphism-by-Default account, we would expect isomorphic uses of "all…not" and "some…not" to be attested more frequently, and at an earlier age, than non-isomorphic uses. Under the QAR theory, we would predict that both kinds of usage would be equally available.

By appeal to the constraint-based approach, we can frame more precise predictions about the production data. First, we expect the utterance to condition the form of correction - that is, the correction that is issued in a given situation will preferentially reuse the quantifier that was uttered by the Cavemom. For instance, we would expect "Q_1 are not" to surface more frequently as a correction to "Q_1 are" than as a correction to a statement involving a different quantifier Q_2. Applying this argument to the question of isomorphism, we predict that "all…not" may surface non-isomorphically as a correction to "all" in the two-item case and "some…not" may surface non-isomorphically as a correction to "some" in the no-item case. This follows from the assumption that quantifier priming is in effect and licenses the use of these expressions even if they are only true on a non-isomorphic interpretation, as discussed earlier. However, forms that would require non-isomorphic interpretations are predicted not to be licensed in other conditions.

In summary, the conditions in this experiment permit us to investigate the development of isomorphic and non-isomorphic uses from a comprehension and production standpoint. This enables us to compare the predictions of the Isomorphism-by-Default and QAR approaches, in addition to evaluating the utility of the constraint-based approach to predicting the choice of correction in general and the availability of non-isomorphic usage in particular. In the following sections we present the experimental methodology and results, and evaluate our hypotheses.

4.3.2. Materials and procedure

The full set of conditions and the semantically correct responses are specified in the results section. The instructions given to child participants were as specified in previous sections: specifically, they were told that the aim of the game was for the Cavemom to say "how many boxes have a toy". They then saw displays of six boxes and heard descriptions of the form "[Quantifier] of the boxes have an [object]".

Adult participants were told that the experiment was designed for children. They were told that the aim of the game was for the character to say "how many toys are in the boxes". They then saw displays of five boxes ('half' was correspondingly omitted from this version of the task) and heard descriptions of the form "[Quantifier] of the [objects] are in the boxes". This difference was introduced so that the adult version of the task would be similar to other tasks administered to the adults in the same session, which investigated related but distinct quantifying expressions (such as comparative and superlative quantifiers). Even though the adult and child versions differ in this way, they are matched in terms of the relation between the question under discussion and the form of the sentences the participants hear.

Two pseudo-randomized orders of the experimental items were created, with the items arranged in such a way as to avoid the use of the same quantifier or object in two successive items. One of these orders was randomly chosen for each participant.

4.3.3. Results

Rates of acceptance across the four test age groups (7-, 9- and 11-year-olds, and adults) are as shown in Table 3.

Table 3: Percentage rates of acceptance for experimental items

Quantifier	**Condition (6-item case)**	**Percentage acceptances**			
		7-year-olds	**9-year-olds**	**11-year-olds**	**Adults**
All	3 items	0	4.17	0	3.33
	All items	100	100	100	96.7
All…not	No items	93.9	94.4	100	82.2
	2 items	6.06	16.7	13.9	22.0
	All items	0	6.67	4.17	6.25
Half	3 items	100	100	100	N/A
	5 items	17	17	0	N/A
Most	2 items	N/A	N/A	N/A	7.5
	3 items	91.7	62.5	66.7	N/A
	4 items	N/A	N/A	N/A	100
	5 items	100	97.9	100	N/A
	All items	N/A	N/A	N/A	10.0

Quantifier	Condition (6-item case)	Percentage acceptances			
		7-year-olds	9-year-olds	11-year-olds	Adults
None	No items	90.9	95.8	100	98.3
	2 items	0	4.17	0	0
Not all	No items	51.5	23.6	22.2	19.2
	2 items	72.7	83.3	95.8	98.3
	All items	0	4.17	0	1.69
Some	No items	0	4.17	0	5.00
	2 items	86.4	97.9	87.5	98.3
	All items	24.2	13.9	11.1	16.0
Some…not	No items	12.1	9.72	16.7	18.3
	2 items	86.4	85.4	83.3	88.3
	All items	0	4.17	0	1.69

For the items that systematically attracted corrections (i.e. were accepted less than 90% of the time by at least one group of subjects), these corrections were as follows.

Table 4: Corrections to rejected utterances; frequency quoted as percentage of total responses

Quantifier	Condition	Corrections (frequency)			
		7-year-olds	9-year-olds	11-year-olds	Adults
All	3 items (child), 2 items (adult)	three (55%) some (18%) some missing (9%) half (9%) most (9%)	some (46%) half (25%) three (13%) other (4%)	half (50%) all…not (17%) some (17%) three (8%) not all (8%)	some (52%) two (15%) not all (12%) three out (5%) some out (3%) most out (2%) other (7%)

Quantifier	Condition	Corrections (frequency)			
		7-year-olds	**9-year-olds**	**11-year-olds**	**Adults**
All…not	No items	none (3%) all…don't (3%)	none (1%) all have no (1%) other (3%)	-	none (17%) other (1%)
	2 items	two (58%) some (27%) a couple (3%) not all (3%) other (3%)	two (42%) some (35%) a third (4%) some…not (3%)	two (44%) some (36%) all…not (3%) most (3%)	some (42%) two (23%) some…not (5%) some out (1%) most (1%) not most (1%)
	All items	all (86%) other (14%)	all (92%) other (2%)	all (96%)	all (93%) other (1%)
Half	5 items	five (17%) more than three (8%) other (50%)	most (25%) five (17%) some (8%) more than half (4%) other (25%) *no response* (4%)	more than half (50%) most (25%) five (8%) all…not (8%) other (8%)	N/A
Most	3 items (child), 2 items (adult)	half (9%)	half (33%)	half (33%)	some (37%) most…not (23%) most…out (22%) two (10%) other (2%)

Quantifier	**Condition**	**Corrections (frequency)**			
		7-year-olds	**9-year-olds**	**11-year-olds**	**Adults**
	All items (adult)	N/A	N/A	N/A	all (90%)
None	2 items	two (45%) some (36%) a couple (9%) all (9%)	two (58%) some (29%) other (4%) *no response* (4%)	two (58%) some (42%)	some (61%) two (39%)
Not all	No items	none (27%) all…not (12%) all out (3%) no (3%) *no response* (3%)	none (58%) all…not (11%) all…no (1%) all…none (1%) all empty (1%) other (3%)	none (75%) all…not (3%)	none (73%) all…not (5%) all out (3%)
	2 items	two (14%) some (5%) none (5%) other (5%)	two (10%) some (6%)	two (4%)	some (2%)
	All items	all (100%)	all (96%)	all (100%)	all (98%)

Quantifier	Condition	Corrections (frequency)			
		7-year-olds	**9-year-olds**	**11-year-olds**	**Adults**
Some	No items	none (82%) all…don't (18%)	none (83%) all…don't (4%) all out (4%) all…no (4%)	none (83%) all…out (8%) not any (8%)	none (90%) all out (5%)
	2 items	two (14%)	other (2%)	two (13%)	other (2%)
	All items	all (76%)	all (86%)	all (89%)	all (84%)
Some…not	No items	none (55%) all…not (24%) not all (3%) other (6%)	none (56%) all…not (19%) all…no (4%) all…empty (4%) no (3%) all out (1%) other (3%)	none (53%) all…not (22%) not any (6%) some…not (3%)	all…not (39%) none (38%) all out (4%) not all (1%)
	2 items	some (4%) two (4%) other (4%)	some (10%) two (2%) most…not (2%)	some (8%) two (4%) most…not (4%)	most…not (12%)
	All items	all (100%)	all (92%) none…not (4%)	all (92%) other (8%)	all (97%) none…not (2%)

4.4. Discussion

In accordance with our first hypothesis, ceiling performance is approached on semantically false items. Younger participants appear to reject semantically true uses of "not all" and "some" to a significant degree, possibly reflecting what they see as inappropriate vagueness in these descriptions (their corrections predominantly involve the precise numeral "two"). "Most" is erroneously accepted by a majority of child participants in each age group, indicating that, as hypothesized, its mastery is delayed by comparison with the other quantifiers under test.

For under-informative items, acceptance rates are between 10% and 60% for all age groups, and highest for the 7-year-olds. Again, this accords with the hypotheses that under-informative items would elicit dissimilar performance from fully informative items, and that younger participants would be more tolerant to under-informativeness. Hence, our results from the control condition accord with predictions derived from the existing literature on the acquisition of quantification (see Katsos and Bishop 2011 for recent data and an overview), suggesting that this task is appropriate for testing child performance in this domain.

With reference to the question of isomorphism, we see that "all…not" is accepted in the no-items condition at rates above 80% for each group under test, but at rates below 25% in the two-item condition for each group (this rate increasing numerically with age). This indicates that non-isomorphic readings are generally unavailable in this experimental context, although their availability appears to increase with age.

Similarly, "some…not" is rejected at rates of less than 20% in the two-item case and accepted at rates of less than 20% in the no-item case (increasing numerically with age). In these cases, the possibility of a non-isomorphic reading is conflated with the question of whether under-informativeness is tolerated. However, these results give little indication that the non-isomorphic reading of "some…not" is available.

Therefore, both sources of comprehension data tend to support the Isomorphism-by-Default account over the QAR account. There is a strong preference for isomorphic readings across all age groups under test, and non-isomorphic readings appear to become increasingly available with age.

With reference to the production task, we are interested in both isomorphic and non-isomorphic uses of "some…not" and "all…not". We assume that productions of "some…not" that occur in 2-items conditions are isomorphic, while those that occur in no-items conditions are non-isomorphic (because these productions come as justifications for rejecting the previous utterance). For "all…not", the reverse is true: productions in

2-items conditions are presumably non-isomorphic, while those in no-items conditions are isomorphic.

As shown in table 4, "all…not" is produced isomorphically in response to "not all", "some" and "some…not" in the no-item conditions. This occurs in all age groups for "not all" and "some not". For "some", "all…not" appears in the two youngest age groups, while "all out" occurs in the older age groups. "Some…not" is produced isomorphically only by the 9-year-olds and adults, and only as a correction to "all…not". Critically, "all…not" is also produced non-isomorphically. It is attested as a correction to "all" in the three-item case and to "half" in the five-item case, both among the 11-year-old group. By contrast, "some…not" is not produced non-isomorphically at all.

These production data appear strongly to support Isomorphism-by-Default over the QAR account. Isomorphic productions of "all…not" are demonstrated at an earlier age and with greater frequency than non-isomorphic productions of "all…not". Of the 98 tokens of "all…not", 95 are isomorphic and only 3 non-isomorphic ($p < 0.001$, binomial). Similarly, for "some…not", 8 tokens are attested, all of which are isomorphic, demonstrating a significant preference for the isomorphic production ($p < 0.01$, binomial).

Turning to the predictions of the constraint-based model, quantifier priming first predicts that the quantifier uttered by the Cavemom will surface disproportionately often in corrections. There is strong evidence of this in the results of this experiment. "Most" + negation is produced in 48% of adult corrections of "most" in the two-item case (27/56 tokens), while occurring in less than 5% of corrections to two-item displays for other quantifiers (10/218 tokens).

Moreover, utterances with explicit post-verbal negation tend to elicit corrections with post-verbal negation: for instance, "all…not" is the preferred adult correction to "some…not" in the no-items case, whereas "none" predominates as a correction to all other prompts in the no-items case. This suggests that some form of syntactic priming is occurring, and that the quantifier priming constraint should be formulated in such a way as to accommodate this.

With respect to the non-isomorphic productions, we note that "all…not" does surface, as predicted, as a correction to "all". However, it also occurs once as a correction to "most", which is not predicted by the constraint-based account. "Some…not" fails to surface as a non-isomorphic production. While this is not necessarily a problem for the constraint-based account, which predicts that these utterances might be available under

certain rankings but does not predict that they necessarily will surface, it does suggest that this account can offer little to the analysis of non-isomorphic productions here.

Nevertheless, the constraint-based account might be relevant to the analysis of the data obtained from this experiment. As observed above, isomorphic instances of "all…not" occur disproportionately often as corrections of "some…not", which appears to reflect some kind of priming effect. By contrast, non-isomorphic instances of "all…not" cannot occur as corrections of "some…not": the former is true in the some-items conditions, for which the latter (on its isomorphic interpretation) is also true and therefore does not require a correction. The same holds for non-isomorphic "some…not", which is true only in the no-items condition for which "all…not" is completely acceptable. Thus, assuming that hearers can always access isomorphic interpretations, considerations of quantifier priming favour the use of isomorphic forms rather than non-isomorphic forms as corrections across the conditions under test in this experiment.

In summary, then, the comprehension data from this experiment provide a clear indication that the preference for isomorphism extends to unbiased contexts, that is in contexts where the Question Under Discussion is satisfied equally well either with the isomorphic or the non-isomorphic interpretation. For the production data, the situation is less clear-cut, despite the considerable prevalence of isomorphic productions, which might at first appear to be compelling evidence in favour of the Isomorphism-by-Default account. This uncertainty arises because of the apparent effect of quantifier priming, as predicted by the constraint-based model, which is shown to condition the choice of correction in several respects, and which may serve to bias the participants towards isomorphic productions in this experimental paradigm.

It should be remarked that the constraint-based model does not constitute a fully-fledged alternative to the Isomorphism-by-Default or QAR accounts. Indeed, it is a tenet of the Isomorphism-by-Default account that the availability of non-isomorphic readings depends upon the hearer's ability to integrate contextual information. From that perspective, the constraint-based model could be seen as a specific and testable proposal as to what contextual information is relevant to the usage and interpretation of the expressions under investigation.

Can we unify these two strands of enquiry by construing quantifier priming effects in terms of QUD? On this view, the participant's decision to use a quantifier again is conditioned by the quantifier used by the speaker, but this motivation is connected with general communicative

considerations rather than due to linguistic form. From this perspective, we could suppose that the participant posits that the speaker intended to address a particular question by their choice of utterance. For instance, post-verbal negation such as in "some of the boxes do not have a toy" might be construed as an attempt to make a statement specifically about the boxes that do not have a toy. If this utterance is false or under-informative (because all or none of the boxes have a toy), the participant may cooperatively attempt to correct the speaker's production in such as way as to respect this QUD. This would involve making a statement to the effect that "all/none of the boxes have a toy", as appropriate. Similarly, the speaker making a statement about "most of the boxes" might indicate that the intended QUD related to the status of the majority of the boxes, and therefore might prompt a correction that "most of the boxes have a toy".

In practical terms, we cannot clearly state that the effects exhibited in these data are attributable to quantifier priming rather than QUD, or vice versa. However, this is not necessarily important, as these two accounts are broadly compatible. Quantifier priming is a mechanism which enables effects such as QUD to be modelled as contributory factors to quantifier choice (in addition to other considerations such as economy of effort). That is, we do not take the view that quantifier priming is a 'deeper' explanation than QUD for the kinds of effects discussed above. Rather, the fact that quantifier priming typically enables QUD to be respected is one of the reasons why quantifier priming is a useful constraint to adhere to in production.

Finally, we should touch upon the question of acquisition. Recall that the availability of non-isomorphic readings is argued to develop with the child's appreciation of contextual licensing factors. From an OT standpoint, we have suggested the relevance of quantifier priming, which is a faithfulness constraint. OT construes acquisition as the re-ranking of constraints, with markedness constraints initially ranked above faithfulness constraints, and the latter moving up during the acquisition process. As McCarthy (2002: 209) puts it, "if the [[M >> F]] initial ranking is also assumed, with demotion of markedness constraints in response to positive evidence, then the observed course of language development ought to begin with only unmarked outputs, followed by inclusion of progressively more marked outputs until the adult model has been matched". From this perspective, we would then expect quantifier priming effects to become more evident with age, with adults being the most willing to use complex expressions in order to satisfy this constraint. Such an effect is arguably evident in the use of "all…not" as a correction of "some…not" in our

experiment. More generally, if non-isomorphic usage is licensed by adherence to a faithfulness constraint such as quantifier priming, this usage should emerge as the speaker develops (and the ability to comprehend the non-isomorphic usage should follow suit), which appears to cohere broadly with the data obtained on the subject so far.

It finally remains to be said that, on the above analysis, non-isomorphic usage behaves like a marked form. This raises the question of whether a markedness constraint requiring isomorphism should be added to the constraint-based model. This would be violated by any choice of utterance which encoded the speaker's intended meaning non-isomorphically. A functional motivation can be suggested for such a constraint. However, it carries the risk of multiplying entities beyond necessity, and weakening the model considerably for modest gains in explanatory power. Nevertheless, it would represent an intriguing step towards positing constraints on the syntax-semantics relation, which could present an interesting outlook for this approach.

5. Conclusion

The constraint-based model discussed in this chapter appears to represent a useful source of hypotheses concerning the meaning and usage of numerically-quantified expressions. In the experimental investigation reported here, we have seen that it can also be applied to other categories of quantified expression, and appears to yield explanations of at least some facets of their usage. In the numerical case, the model does not contribute directly towards determining the semantics of expressions, but serves to make predictions as to the pragmatic enrichments arising from their usage, and in doing so may illustrate whether certain semantic stipulations must be made. Similarly, as applied to the problem of isomorphism, the model does not go to the heart of the question of why isomorphism might be preferable, but does appear to shed some light on the pragmatic consequences of this preference, which in this case bolsters the argument that the preference for isomorphism is not reducible to contextual considerations alone.

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