Toward a Unified Computational Model of Quantificational Scope Readings*

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Abstract. This paper is aimed at uncovering a unifying computational grounding beneath a diverse range of cases of quantificational scope effects both within and across languages. Since quantificational scope readings are quite variable and interspersed with issues of modularity and interfaces of grammar, an underlying and universal generalization is certainly hard to come by. Research on quantification is not new at all; studies and research done on quantification have not yet been able to arrive at a useful but universally valid and satisfactorily unified account of how quantificational readings are derived at all, let alone computationally. Here in this paper, a preliminary sketch of a unified three-tier computational model will be drawn up to show how quantificational scope readings across languages can be computed and derived. For this purpose, principles drawn from recent derivational accounts of quantificational scope will be aligned properly to eliminate their incompatibilities with each other.

Keywords: a unifying computational grounding, quantificational scope, computational model.

1 Introduction

Quantification is one of the hottest topics in linguistic research where the issue of how syntax maps into semantics is invariably associated with the question of how constrained the syntax-semantics interface is. If quantification is a linguistic phenomenon which is operative at the syntax-semantics interface, the question that naturally arises is: how much contribution does syntax as opposed to semantics or vice versa make toward a heterogeneous set of scopal effects that we find in quantificational readings within and across languages? When do syntax and semantics interact for variable scope effects in quantificational readings? Issues of such kind are certainly convoluted given that quantificational interpretation is not a unified phenomenon (Ruys and Winter, 2010; Szabolcsi, 2010). Given the backdrop above, we find that quantification has been handled from a number of perspectives- set-theoretic, representational, derivational etc. (see for details, Ruys and Winter, 2010). Here in this paper, present derivational accounts of quantificational scope will first be considered. The principles proposed in those accounts have computational significance in the operational design of the language faculty. But they will be shown to be incompatible and inconsistent with each other. A unifying account that eliminates their inconsistencies but aligns them beautifully in a computational model so that the correct generalizations about quantificational scope readings across languages can be captured is therefore needed.

2 An Outline of the Background Landscape

An initial but brief survey of some of the current derivational approaches towards quantificational scope readings will first be presented. And then some problems associated with them will also be drawn up in later sections just to show how it calls for a unifying account of computational operations underlying quantificational scope.

Fox (2003) has argued that QNPs (Quantificational Noun Phrases) move mainly because they need their argument requirement to be satisfied. The motivation behind this is simply that QNPs having the denotation of second-order predicates take predicates as their arguments, but their arguments which are in a sister position in a tree are to be one-place predicates. If the arguments in sister position are not one-place predicates, QNPs move to a position where this requirement can be satisfied. So, for example,

(1) I climbed every tree.

for (1) above we get [every tree]$_1$ [I climbed t_1].

In addition, Fox has also argued that QR (Quantifier Raising) in many cases is sensitive to syntactic constraints like coordinate structure constraint, VP parallelism, binding principles etc. Sauerland (1999) has, in addition, shown QR to be sensitive to *Relativized Minimality* effects. Elsewhere Fox (1999, 2002) has argued that quantifier scope in terms of both QR and QL (Quantifier Lowering) is subject to *Economy Constraint* which stipulates that a scope shifting operation will be allowed only when that brings forth a semantic interpretation, and if two scope shifting operations can yield the same semantic interpretation, the one with shorter movement or with no movement will be preferred. The examples below show this clearly

(2) A man loves every girl.
(3) John loves every girl.

In (2), 'a man' can take scope over 'every girl' and vice versa; but it is not possible in (3) because the movement of 'every girl' will not lead to any new semantic interpretation, so *Economy Constraint* will ban this movement. He also adds that syntax is not fully autonomous as it can see the effects of quantificational scope readings in that syntactic constraints like parallelism in ellipsis constructions, and coordinate structure constraint can affect QR and QL. Quite apart from these, Fox and Nissenbaum (1999) have even posited that the output of QR can be taken as input to overt operations of Merge. So in cases like the following, Fox and Nissenbaum have argued that

(4) a. We saw [a painting (t_i)] yesterday [from the museum]$_i$.
b. We saw [a painting (t_i)] yesterday [by John]$_i$.

the moved constituent is an adjunct, so it can be merged late through QR of the NP (the adjunct is associated with) to a higher position on the right, and then the merger of the adjunct to it. So by virtue of this, QR can happen in the overt component of grammar and there is no need for covert LF (Logical Form). Tracing quantification from another stance, Beck (1996) has, on the other hand, has argued that quantified structures can block LF movement of wh-elements, other quantifiers and also restrictive elements of DPs. This is shown below in (5) where 'niemand' blocks the movement of 'wo' at LF.

(5) ??Wen hat niemand **wo** gesehen?
whom has nobody where seen
'Where did nobody see whom?'

According to Beck, such intervention effects of quantificational structures can also explain quantifier scope in German.

In a different vein, Beghelli and Stowell (1997) have tried to account for quantificational scope patterns in terms of a functional hierarchical ordering of different QNPs which move for reasons of feature checking. So for instance, DQPs (Distributional Quantifier Phrase) like 'every', 'each' have a fixed position in the functional hierarchy- DistP where they always move and GQPs (Group-denoting Quantifier Phrase) like 'some boy' etc. have two positions- RefP and ShareP: one above DistP and the other below it. Such ordering can explain scope reversals of universals vis-à-vis existentials, for example.

On the other hand, Aoun and Li (1993) have provided an account of scopal interpretation across languages like Chinese, English in terms of two principles: *Minimal Binding Requirement* (which stipulates that variables must be bound by their most local A-bar binder) and *Scope Principle* (which states that a quantifier A may have scope over a quantifier B iff A c-commands a member of the chain containing B). So for a sentence like the following

(6) Every man loves a woman.

The two interpretations can be derived this way. In the first, the QNP 'every man' c-commands the QNP 'a woman', so the former can scope over the latter. In the second case, the QNP 'every man' will move overtly from the specifier of the verb phrase leaving a trace and then the QNP 'a woman' will move covertly to get adjoined to VP at LF and now can c-command the trace of the QNP 'every man', a member of the chain containing the QNP 'every man'. So 'a woman' can scope over 'every man' as well.

3 The Problems with the Linguistics of Quantification

It can now be said that quantifier scope effects are not uniform in their behavior in that there is no single unifying linguistic principle or constraint that can account for all kinds of patterns of quantificational readings both within and across languages (Szabolcsi, 2010). As will be made clear and shown below, the accounts proposed so far just fall short of having broader and far-reaching generalizations, and often they are also inconsonant or incompatible with each other. With this, within this theoretical niche laid out, a set of crucial questions can be raised.

First, do all QNPs move to be in a position where their sisters will be one-place predicates? Is it a cross-linguistically valid generalization? Let's look at some examples.

(7) I gave a child each doll.
(8) A child gave me each doll.
(9) She didn't give me many dolls.

Here in the examples above, as Bruening (1999) argues, in (7), the universal quantifier cannot outscope the existential quantifier, but in (8) it can and in (9) the proportional quantifier can outscope the negation. In all the three sentences each second object quantifier has a two-place predicate as its argument in the sister position in the tree if Larson's (1988) VP shell analysis is adopted.

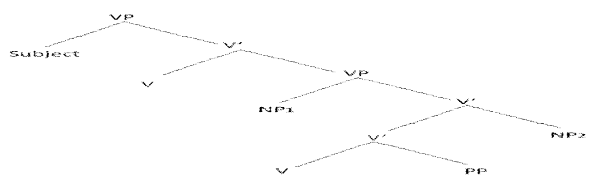

Figure 1: Larson's VP shell analysis for double objects

Here the place occupied by NP1 (indirect object) was earlier occupied by NP2 (direct object) which is demoted to adjunct position, and then the indirect object moves up after the preposition vanishes and it moves up for the purpose of case assignment. The verb will then get adjoined to the VP head above. So under this construal, why do the QNPs move in (8) and (9) but not in (7) even if in all three cases the predicate is not a one-place predicate? Similarly, Fox's (2003) own example sentence poses a problem for this kind of analysis for the movement of QNPs.

(10) I climbed every tree.

In this case, even if 'climb' is not a one-place predicate, the QNP 'every tree' cannot move up to outscope the subject as it will not create a different scopal interpretation. Moreover, Beck's (1996) account of quantified structures acting as interveners for *wh*-elements, other quantifiers and also restrictive elements of DPs as applicable in German (to be discussed below) can be put forward as a stronger case against the hypothesis based on QNP one-place argument requirement analysis. Let's consider the sentence below as given by Beck.

(11) a. Luise glaubt, dab fast jeder Esel keinen Semantiker gebissen hat
Luise believes that almost every donkey no semanticist (Acc) bitten has
'Luise believes that almost every donkey bit no semanticist.'
b. *For no semanticist y: almost every donkey bit y.

As shown above the meaning in (b) is not possible even if 'gebissen' is a two-place predicate. All this strongly suggests that the above account of QNP movement is based on a very shaky ground. So the answer to the question posed above "do all QNPs move to be in a position where their sisters will be one-place predicates?" is perhaps in the negative given the empirical data shown above.

Second, if QR/QL is subject to *Economy Constraint*, as Fox (1999, 2002) argues, then what is the intrinsic nature of *Economy Constraint*? It seems that *Economy Constraint* is an interface constraint since it basically says that a scope shifting operation will be allowed only when that brings forth a semantic interpretation, and a scope shifting operation is a syntactic operation of movement with no phonological consequences but with semantic consequences in terms of interpretations. Fox has shown how *Economy Constraint* interacts with grammatical (syntactic) constraints like parallelism in ellipsis constructions, and the coordinate structure constraint in different scope effects. This means that *Economy Constraint* applies at LF and grammatical constraints which apply in overt syntax can also spread into covert syntax at LF and affect LF movement. *Economy Constraint* so plays out in both syntactic constraints and semantic interpretations.

But then there are problematic cases that Fox's account has given rise to. He deals with the capacity of existentials to scope over universal quantifiers in an island intervening construction (see for details, Fodor and Sag, 1982) in terms of existential closure over choice function that gets the existential in such cases having higher scope than the universal quantifiers, as in the following

(12) a. Every professor heard the rumor that three students of mine failed the test.
b. (∃f) Every professor heard the rumor that three f(students of mine) failed the test

This is what explains why the sentence in (13) below

(13) Every boy admires a certain professor and Mary does too.

does not obey his *Ellipsis Scope Generalization* (ESG) constraint which bans ambiguity in the first conjunct if the second is unambiguous as it appears to be the case in (13) but in fact does not hold true. The reason is that choice function over the existential can explain it in the following way

(14) (∃f) Every boy admires f(professor) and Mary admires f(professor).

Choice function does not involve either QR or QL, so this does not involve movement at all (Reinhart, 1995). Hence there are strong grounds on which we can say that this mechanism is extra-syntactic. So is the quantification over world-time pair in generic quantification which also does not involve QR/QL. This mechanism allows nominals including QNPs having wide scope without movement. So they cannot possibly operate at LF which is actually a syntactic level. But Fox assumes that sentences getting scope interpretation in such cases can be assigned LF representations with choice functions and generic quantification. How is that possible? If these extra-syntactic mechanisms do not involve movement, they should also operate beyond LF in that LF movement is fundamentally a syntactic movement without phonological consequences. Worse still is the fact that in the case of generic quantification as in the following,

(15) A guide accompanies every tour to the Eiffel Tower, and Jeanne does, too.

Fox argues that it obeys economy and parallelism: the first one is an interface constraint and the second a syntactic one. If generic quantification is extra-syntactic, then how can it obey parallelism and even economy (which has movement constraint built into it)? For Fox to be right, both generic quantification and existential closure over choice function have to be a part of *Numeration* in that both generic quantification and existential closure might involve quantificational elements which are not a part of the initial choice of lexical items as Fox (2002) himself has maintained; otherwise that will violate *Inclusiveness Condition*. This is more due to the fact that generic tense acts an operator that quantifies over situations (Fox and Sauerland, 1997), and existential closure over choice function is itself a function operator which is not for the existential itself. That is why in the sentence below

(16) One professor heard the rumor that three students of mine failed the test.

we cannot get a distributive interpretation where professors vary with respect to a group of three students as 'three students' cannot have wide scope with respect to 'one professor' (Fox, 2002).

However, the standard assumption is that these mechanisms (generic quantification and existential closure) cannot be a part of syntax per se. Could we then say that choice functions and generic quantification are certainly beyond LF, but syntactic constraints can move out beyond LF to affect them? We are not sure.

Third, Fox and Nissenbaum's (1999) proposal raises another problem for LF movement and QR/QL. If both QR and possibly QL can be the input to overt operations and can thus occur in overt syntax with phonology targeting the head of the chain (after copy operation) which is equivalent to overt movement, and the tail of the chain which is equivalent to covert movement, why will we still need a level like LF at all? LF is a syntactic level where syntactic computations are made for semantic interpretations. In such a case the architecture of grammar will perhaps look like the following:

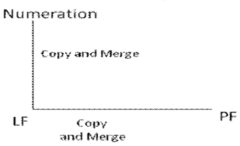

Figure 2: The assumed architecture of grammar in Fox and Nissenbaum's (1999) proposal

If this is the architecture of grammar, LF will perhaps be redundant since what role would LF play in an architecture like the above where everything happens in overt syntax and it is phonology that determines what is to be pronounced and what not when linearization occurs. Even if we are aware of the fact that LF is independently motivated for the implementation of *binding theory* to occur, but where *binding theory* applies is still a moot point; Hornstein, Nunes and Grohmann (2005) have, for example, argued that it applies at C-I interface (see for a different proposal, Lebeaux, 2009). But the most tantalizing question that remains is that: where would semantic interpretation occur? It cannot happen at the point where LF exists since Copy and Merge can apply after QR/QL which is supposed to occur at LF and therefore semantic interpretation will remain incomplete, thus violating *Full Interpretation*. This is also at odds with the Fox's (2002) account of quantificational scope readings which are subject to *Economy Constraint*. *Economy Constraint* is an interface principle as specified above. And this applies at LF and interfaces, on one hand, with syntactic constraints like parallelism in ellipsis constructions, the coordinate structure constraint etc., and on the other, with semantic interpretational effects. If this is so, then where would *Economy Constraint* apply in the architecture above? By principle, it has to be operative at an interface which is like a way-station between syntax and semantics-something like LF in the standard model; but in the architecture above where everything occurs in overt syntax and LF computations are also overt, LF ceases to be an interface level. It no longer acts as the level for the syntactic contribution toward semantic interpretation, since LF has been isolated from its interface with the C-I (Conceptual-Intentional) system.

Fourth, Beck's (1996) account of quantified structures acting as interveners for *wh*-elements, other quantifiers and also restrictive elements of DPs is applicable in German, and she argues that this may be applicable in other languages too with some modified version of his principle called *Minimal Quantified Structure Constraint.* If LF movement as opposed to overt movement can thus be blocked by quantificational structures at LF, this raises the possibility that there are strong conceptual and empirical motivations for LF, and this is what will turn out to be a strong case against the account of overt QR in Fox and Nissenbaum (1999). If everything happens in overt syntax, why do we get such LF intervention effects that Beck has shown to be missing in overt syntax? How is this reconcilable with Fox and Nissenbaum's overt QR account?

Quite apart from these issues, Beck's constraint poses some other problems for quantificational scope readings based on semantic mechanisms and constraints. Beck's *Minimal Quantified Structure Constraint* is a purely syntactic constraint and it disallows certain otherwise possible semantic interpretations. What kind of implications does it then have for syntax-semantics interface? Does this mean that an interface principle like *Economy Constraint* can be violated in favor of the requirements for satisfaction of a syntactic constraint like *Quantified Structure Constraint*? Is it all syntactic constraints that determine semantic interpretations? Is this relative to linguistic phenomena across some languages but not others or absolutely fixed?

Beck's *Minimal Quantified Structure Constraint* poses problems for Beghelli and Stowell's (1997) account of quantificational scope readings and for Aoun and Li's (1993) account too. If Wh-QPs all move to Spec-CP in Beghelli and Stowell's functional hierarchy of phrases, why cannot 'wo' in (5) above move to Spec-CP at LF even if it can do so in the absence of 'niemand' as Beck has shown? Then the example in (11) casts doubts on Aoun and Li's (1993) account in that here *Minimal Binding Requirement* as opposed to *Scope Principle* will be applicable because for *Scope Principle* to be applicable, there must be a movement of the subject QNP 'jeder Esel' in surface structure so that a trace is left and when the object QNP 'keinen Semantiker' moves covertly at LF it will c-command the trace of subject QNP 'jeder Esel'; but the question is: why and on what ground should one assume that one rather than the other constraint should apply in a given case? Is not it a restatement of the problem itself since for a certain scopal interpretation the one that fits the interpretation is being called for? Why should English differ from German in whether *Minimal Binding Requirement* or *Scope Principle* is being applied?

4 An Alternative Unified Computational Model of Quantifier Scope Readings

Now an outline of an alternative but unified account of quantificational readings can be fleshed out. Before moving on, let's clarify a number of things. The account will be presented in the form of a computational model where principles and constraints found to be applicable to quantificational readings across and within languages as shown above would serve as computational primitives. What are required at this stage are an elimination of the mutual incompatibilities among those principles and constraints, and a grounding of them in a model where their computational operations are properly aligned with respect to each other so that all this nicely fits into the data. Such a computational grounding can have repercussions for the design and architecture of the faculty of language itself, though the computational model is posited here without any direct commitment to a specification of the optimal architecture of language. Relevant but brief discussion on this would be put off until the exposition of the model. Let's now move on to the core machinery of the model.

4.1 An Underlying Basis of Quantificational Scope

Here it will be argued that quantificational scope is underlyingly antisymmetric, that is, quantificational scope is at bottom antisymmetric. A relation R is antisymmetric if whenever (a, b) ϵ R and (b, a) ϵ R, then a = b. So according to this, a set A = {(1, 2), (2, 1)} is not antisymmetric since 1 ≠ 2. Note that when it is said that quantificational scope is underlyingly antisymmetric, it is defined on the hierarchical structure of the sentence/clause. Let's now see how it works for quantificational scope defined on quantifier phrases. The example in (6) which is repeated below can be taken here

(6) Every man loves a woman.

Here the QNP 'every man' is higher than the QNP 'a woman' in the hierarchical tree structure of the sentence. Let's call the universal 'a' and the existential 'b'. So the relation that obtains is R = { (a, b) } which is antisymmetric according to the definition above. What if we take a sentence of the kind below?

(17) Every man loves every woman.

Here again the relation will be R = { (a, a) } and obviously a = a. How does it work for sentences with more than two QNPs or quantificational elements? Let's see how in the following sentence.

(18) A writer did not destroy every work.

Here the relation would look like R = { (a, b), (b, c), (a, c) } where 'a' is the existential, 'b' is the negation and 'c' is the universal. It is again antisymmetric. What about QNPs strung out in more than one clause? Let's take the following example,

(19) Many people knew that a linguist had appeared for every dinner.

Here the antisymmetric relation that would obtain is: R = { (a, b), (b, c), (a, c) } where 'a' denotes proportional quantification (in 'many people'), 'b' denotes the existential (in 'a linguist) and 'c' the universal (in 'every dinner'). For coordinated sentences, antisymmetry would hold separately in each conjunct as in the sentence in (13) repeated below

(13) Every boy admires a certain professor and Mary does too.

Here we get two relations: R_1 = { (a, b) } and R_2 = { (c, d) } where 'a' refers to the universal (in 'every boy), 'b' and'd' to the existential (in 'a certain professor') and 'c' to Mary.

More interesting are cases of Hintikka sentences (taken from Gierasimczuk and Szymanik, 2009). Let's see one example below

(20) Some book by every author is referred to in some essay by every critic.

Here is R = { (a_1, b_1), (a_2, b_2) } which is antisymmetric and where a_i = existential, b_i = universal. Since R is a set, it preserves the symmetric order of the two 2-tuples as it conforms to two-way reading (Gierasimczuk and Szymanik, 2009). So we can also write R = { (a_2, b_2) , (a_1, b_1) }.

4.2 Quantificational Scope Reading is a Process of Antisymmetry Breaking: A Unified Computational Model

Now it will be shown that quantificational scope reading is nothing but a process of antisymmetry breaking in an ordered sequence of computational operations involving a set of principles and constraints which act as computational primitives. For the sake of simplification, let's say that there are three types of computational primitives based on the level or tier at which they apply. The first is Fox's (1999, 2002) *Economy Constraint*. Let's call it **E**. The second is a set of grammatical or syntactic constraints $\mathbf{C_n}$ like *Parallelism* in ellipsis constructions, *Coordinate Structure Constraint*, *Minimal Binding Requirement, Scope Principle*, *Minimal Quantified Structure Constraint, Relativized Minimality* etc. and the third is a set of extra-syntactic or non-movement mechanisms like generic quantification and existential closure. Let's call this set **M**. What is of utmost importance here is that there is an order in which these three kinds of computational primitives operate so that the correct generalizations regarding quantificational scope readings can be captured and the incompatibilities pointed out above can be abolished. The order is the following:

$$\mathbf{E} \longrightarrow \mathbf{C_n} \longrightarrow \mathbf{M} \qquad (1)$$

This is the algorithmic picture of the computational operations performed and executed in three tiers or levels by the three kinds of computational primitives. What this means is simply that *Economy Constraint* will apply first irrespective of whatever happens followed by the application of a subset of the set of grammatical or syntactic constraints $\mathbf{C_n}$, and at last a subset of the set of extra-syntactic or non-movement mechanisms **M** will apply. This ordering in the computational operations breaks antisymmetric relation of quantifier scope at any point in the sequence of the ordering or throughout, as will be shown below- though antisymmetry can also be restored in certain cases. Before we proceed, there are only two assumptions to be stipulated:

i. Later constraints can alter the outputs derived at earlier tier or level.
ii. At no point will the same output produced at an earlier level or tier be reproduced.

Let's now look at concrete examples to see how it all works. Let's take the example given in (6), repeated below

(6) Every man loves a woman.

Here the antisymmetric relation is R = { (∀, ∃) } which will first be put to **E** which dictates that both ∀ > ∃ and ∃ > ∀ are possible as far as semantic interpretation is concerned. So the antisymmetry will get broken as the new relation obtained is R = { (∀, ∃), (∃ ,∀) } where ∃ ≠ ∀. Then $\mathbf{C_n}$ will apply, but there is none to be applicable here. So goes for the last level where **M** applies. The scopal effects in the sentence in (21) below (taken from Fox, 2002)

(21) Some boy admires every teacher and Mary does too.

can also be easily accounted for. The antisymmetric relations are R_1 = { (∃ ,∀) } for the first conjunct and R_2 = { (Mary, ∀)} for the second. **E** will apply first and in the first conjunct we will get R_1 = { (∃ ,∀) , (∀, ∃) } and for the second R_2 = { (Mary, ∀)}. Then *Parallelism* constraint in ellipsis constructions in $\mathbf{C_n}$ will cancel out (∀, ∃) and the R_1 would turn into R_1 = { (∃ ,∀) }. And then comes the turn for **M** which will be inapplicable here. So we again get the correct quantificational reading.

The above computational process also easily explains the problematic case in (12) where existential closure over choice function is called for. The antisymmetric relation is R = { (∀, ∃) }. **E** will apply and we shall get R changed into R = { (∀, ∃), (∃ ,∀) }; then nothing from $\mathbf{C_n}$ will be applicable in the next level. When it comes to **M,** existential closure over choice function will apply and R = { (∀, ∃), (∃ ,∀) } will be maintained as it conforms to the to-be-produced output of existential closure over choice function by obeying the stipulation in **(ii)** above. The sentence in (13) has a virtually similar account. The antisymmetric relations are R_1 = { (∀ ,∃) } for the first conjunct and R_2 = { (Mary, ∃)}. **E** will apply and we would get R_1 as R_1 = { (∀, ∃),(∃ ,∀) }. Then *Parallelism* constraint in ellipsis constructions from $\mathbf{C_n}$ will cancel out (∃ ,∀) from R_1. **M** will apply thereafter and existential closure over choice function will bring back (∃ ,∀) to R_1. Thus we get the correct result again. The same goes for (15) too. Here The antisymmetric relations would be R_1 = { (∃,∀)} for the first conjunct and R_2 = { (Jeanne, ∀)}. **E** applies first outputting R_1 ={ (∃ ,∀) , (∀, ∃) }. *Parallelism* constraint in ellipsis constructions from $\mathbf{C_n}$ will rule out (∀, ∃) and then **M** will bring it back to R_1 as it existed after **E** applied. But here the relevant operation is generic quantification in **M**. So the correct result is obtained.

The example in (11) is also nicely explained as it triggers a conflict between *Economy Constraint* and *Minimal Quantified Structure Constraint*. Here the antisymmetric relation is R = { (∀, ∃) }. **E** applies first establishing R = { (∀, ∃), (∃ ,∀) }. Then *Minimal Quantified Structure Constraint* from $\mathbf{C_n}$ applies and rules out (∃ ,∀). At the last level, **M** turns out to be inapplicable. We get the correct result easily without any conflict. This computational account can also accommodate the fixed surface scope interpretation in Chinese where, as Aoun and Li (1993) argue, *Minimal Binding Requirement* applies. So for a Chinese equivalent of the sentence like (6), even if **E** incorporates ∃ > ∀ into R = { (∀, ∃) }, the antisymmetric relation; *Minimal Binding Requirement* at the next level will eliminate ∃ > ∀ from R. **M** will be inapplicable in the next level. So we get the correct result. Interestingly, this will also hold for other bare LF languages like Japanese, Hungarian etc. The computational model above also accounts for Chinese passives where scope reversals occur and for English double object constructions where only surface scope is possible (Aoun and Li, 1993). In the former, **E** will demand both ∀ > ∃ and ∃ > ∀ and at the second level of the computational process *Scope Principle* will retain this as this corresponds with its would-be output by following the stipulation in **(ii)**. **M** will be inapplicable at the last level. And in the latter case of English double object constructions, even if **E** brings both ∀ > ∃ and ∃ > ∀, *Minimal Binding Requirement* in $\mathbf{C_n}$ will ban either of them depending on the surface scope. **M** will be inapplicable at the last level. Thus the correct generalizations are captured again.

5 Concluding Remarks

The unified computational model of ordered computational operations of principles and constraints correctly accounts for cross-linguistic generalizations about quantifier scope readings in a simpler way. It all suggests that for **E** to operate, we need something like LF in the design architecture of grammar, and cases of late merger after LF (Fox and Nissenbaum, 1999) might need a reconfiguration of the architecture of language faculty. However, the only cost accrued in the model is the presence of redundancy where earlier outputs are sometimes put back at a later level. But language has features of redundancy and so does brain have. since it is a computational model, its redundancy is compensated for by its wide generality in producing the correct empirical generalizations. Koller and Thater (2010) have provided a computational model of weakest readings of quantificational scope, but the model explicated here aims at something different- to model differential scope patterns across a range of empirical data. Further cross-linguistic research is necessary for this.

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