3

Quantification at the interfaces

3.1 Introduction

In this chapter, I will argue that the essential task the child acquiring a language is faced with is to establish a target-like equilibrium between syntax, semantics and pragmatics. The requisites for an adult understanding of quantified sentences involve untangling exactly how and when each of the different kinds of constraints apply in the target language (see chapter 3.2). This main hypothesis (which I will introduce in section 3.3) will function as the starting point for exploring children’s understanding of quantified sentences in subsequent chapters. After distilling precise predictions from this hypothesis and discussing these predictions in the light of previous research, I will show in section 3.4 that Optimality Theoretic semantics (Hendriks and De Hoop, 2001) enables us to test this hypothesis with new experiments on children’s understanding of quantified expressions.

3.2 Quantification at the interfaces

In chapter 2, I showed that the syntactic structure of a quantified sentence determines its meaning. In this respect, quantified sentences do not differ from other sentences and obey the well-known principle of compositionality, stating that the meaning of every linguistic utterance is determined by its parts and the way these parts are (syntactically) combined. However, touching on a subject that has been around in the literature for centuries, it is one thing to determine the meaning of a sentence an sich, but it is another to determine the meaning of a sentence in its discourse context. Moreover, given that the truth value of a quantified statement depends on the actual world or a picture that functions as the domain of interpretation, the visual context also plays a role (cf. for example Coventry, Cangelosi, Newstead, Bacon, and Rajapakse, 2005). In the next two subsections, I will explore pragmatic constraints on the meaning of quantifying expressions. I will conclude that, without disregarding any of the syntactic and semantic constraints on quantification identified in chapter
2, these pragmatic constraints also have to be taken into account in the acquisition of quantifying expressions.

### 3.2.1 Discourse context

The quantifier *many* is known for its context-dependent meanings. Consider the following example:

(1) Many European soldiers are fighting in Iraq

   a. U.S. Secretary of Defense: “Many European soldiers relative to the number of American soldiers, are fighting in Iraq” (FALSE)
   b. ECFR: “Many of the total number of soldiers in each European country, are fighting in Iraq” (TRUE)

Given the criticism of the U.S. Secretary of Defense Robert Gates that the European countries did not contribute sufficiently to the war on terrorism (*Spits*, February 14th, 2008), he apparently took (1) to be false. A survey by the European Council on Foreign Affairs (ECFR) showed that Europe contributed to a larger extent to the war in Iraq than America did; Europe spent more money compared to the USA to send soldiers to Iraq. Therefore, (1) was actually true. However, this was clearly not the meaning Gates intended and the rumor continued that Europe should contribute more to the war in Iraq.

Example (1) clearly illustrates how one’s world knowledge or the discourse context in which the sentence is uttered determines its truth conditions. This is not limited to sentences with the quantifier *many*. Various examples can be found in the literature illustrating in a similar way that one has to take the discourse context into account to interpret quantifying expressions. Consider the following examples and their intended meanings (see for other examples and a discussion of the relation between the intended meaning and the syntactic structure of such sentences, chapter 5).

(2) Have you put all the knives on the table? (from Donaldson and Lloyd, 1974,66)
   “Have you put all the knives that are needed, on the table?”

(3) The burglar took everything (from Recanati, 1986)
   “The burglar took all the valuable/important objects, when he broke into the house”

(4) Every German is proud of his car (from Geurts, 1999:281)
   “Every German who owns a car is proud of it”

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1 The issue returns in different forms in the literature as tacit quantifier domain restriction or context dependent quantifier domain restriction. In psychology, ‘schemata’ often refer to the need to recover background information to determine the meaning intended by the speaker. For references, see the remainder of this chapter and chapter 5 and 6.
In addition to the syntactic and semantic properties of quantified sentences discussed in chapter 2, pragmatics plays a role in determining the meaning of these sentences. As De Hoop, Hendriks, and Blutner (2007) point out, the interaction between context and linguistic properties of quantifiers poses a major problem for linguistic theories that take a traditional perspective on meaning (i.e. theories that take the principle of compositionality as defined above as a starting point). As Hendriks and De Hoop (2001) put it:

... building interpretation on syntactic structure alone has serious shortcomings. Context as well as intonation play a major part and the question arises when, how and to what extent people use different principles to arrive at the proper interpretation of a quantified expression in a given context. (2001:6)

Such a view on interpretation differs from the classical view of compositionality in linguistics and led people working in the so-called ‘radical pragmatics school’ (see for instance Cole, 1981) to conclude that the actual meaning expressed by a proposition is more than the meaning of only the sentence. Postponing this discussion to chapter 5, at present, I take it to be the null-hypothesis that the meaning of quantified sentences crucially involves the interaction between syntax, semantics and the discourse context.

3.2.2 Visual context

A growing body of literature uncovers the effect of the visual context on adults’ interpretations of quantified sentences. Freeman, Sinha, and Stedmon (1982) report that adults answer “no, that one”, in a similar way as children (see chapter 2) for a sentence like (5) with respect to figure 3.1 (cf. also Brooks and Sekerina, 2006).

(5) Are all the cups on the saucers?

Freeman et al. take this to mean that adults mirror children’s behavior. Adults seem to restrict all the cups to “all the cups which ought to be present” (Freeman et al., 1982:64), illustrating that adults restrict a quantifier domain by means of the perceived purposes and intention of the speaker.

As pointed out by Braine and Rumain (1983) (cf. Geurts, 2003), research addressing adults’ abilities to reason logically illustrates in a similar way that adults sometimes give answers similar to children’s symmetrical answers (see, among others, Newstead and Griggs (1983) and references therein). Newstead and Griggs (1983)

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2The term ‘pragmatics’ should be understood here, and throughout this thesis, in terms of Sperber and Noveck’s (2004) ‘pragmatics in the narrow sense’. This contrasts with ‘pragmatic in the broad sense’ which involves the study of language use (ranging from, for example, the relation of language to gesture and social ethnic customs). Pragmatics in the narrow sense, however, involves the study “how linguistic properties and contextual factors interact in the interpretation of sentences” (Noveck and Sperber, 2004:1).
Figure 3.1: Extra-object situation for the test sentence *Are all the cups on the saucers?*

asked adults whether “All Y are X” follows from “All X are Y”. 34% of the 96 adults believed that “All Y are X” indeed implied that all X were also Y. Whatever causes adults to make these errors, I take these so-called illicit conversions to illustrate that adults sometimes use different clues than syntax to interpret a quantified sentence.³

Newstead and Coventry (2000) and Coventry et al. (2005) provide further support for the hypothesis that visual information plays a role in adults’ interpretation of quantifiers. Their work shows that both the spacing and grouping of the sets denoted by the quantifier restriction and nuclear scope affect adults’ judgments of quantified sentences. For example, whether (6) is judged as true or false depends on the relative size of the balls in the bowl - i.e. true when the balls fill the entire bowl and false if the balls are small and just fill a small part of the bowl (Newstead and Coventry, 2000).⁴

(6) There are many balls in the bowl

Trueswell, Sekerina, Hill, and Logrip (1999) points at the interaction between language comprehension and visual context. They found that adults use the visual context to interpret temporarily ambiguous phrases like (7). This sentence is,

³In line with these findings, recent studies using brain-imaging techniques like fMRI and addressing adults’ understanding of quantified sentences in the context of a logical reasoning task, show that the visual cortex is activated when adults are asked to interpret quantified statements, even when the stimuli are presented only verbally (see Knauff (2007) and references therein).

⁴More generally stated, Coventry et al. (2005) conclude that language comprehension “maps onto perceptual processing” (Coventry et al., 2005:511). This is consistent, as they point out, with recent findings on the relation between language comprehension and perception (see Coventry et al. and references therein).
without any visual context, temporarily ambiguous between the so-called ‘modifier’
interpretation (7-a) and the so-called ‘destination’ interpretation (7-b); the DP on the
napkin can either indicate where the frog is or where the frog has to be put.

(7) Put the frog on the napkin on the box
   a. Put the frog [on the napkin]_{modifier} in the box
   b. Put the frog [on the napkin]_{destination} in the box

Trueswell et al. (1999) asked adults to carry out the instruction in (7) in two different
visual contexts. In the so-called ‘2-referent’ context, there were two identical animals
(e.g. two frogs), providing two possible referents for the noun phrase the frog. One
animal was sitting on the table, and the other animal was sitting on an object (e.g.
a napkin). Two other objects were displayed, an empty napkin and an empty box. This
visual context was designed to elicit the modifier interpretation; it is unclear
which frog the frog in the 2-referent context refers to, and so adults are hypothesized
to chose a modification interpretation of on the napkin (understanding this PP to
specify the intended referent). The ‘1-referent’ context was designed to elicit the
destination interpretation. This context was identical to the other context, except
that now there were two different animals (e.g. a frog and a horse). Because the
frog now unambiguously refers to the frog, on the napkin is hypothesized to get a
destination interpretation (which then leads to a garden path error). The results
show that when adults were asked to interpret (7), they indeed choose the modifier
interpretation when the visual context supported it (i.e. in the 2-referent context)
and the destination interpretation when the visual context indicated that a modifier
interpretation was unnecessary, i.e. in the 1-referent context. This, Trueswell et
al. (1999) claim, is consistent with the hypothesis put forward by, among many
others, Tanenhaus, Spivey-Knowlton, Eberhard, and Sedivy (1995) that the language
processing system is highly interactive and leads them to conclude that adults’
interpretations can be manipulated by visual context.

So exactly what in the visual context guides adults’ interpretation of linguistic
structures? Donaldson and Lloyd (1974) suggested that the Gestalt principles of
perception might be relevant. Gestalt psychologists took perception to be a matter
of responding to large, whole patterns. They identified six principles of perception,
of which the Principle of Pregnanz captures the process behind these six principles.
This principle states that the perceptual system strives to perceive whole, organized
patterns (i.e. with a symmetrical, regular and predictable shape). In some cases,
this principle is so powerful that it is responsible for visual illusions. This explains
why adults perceive a white triangle in figure 3.2; the tendency to perceive whole,
organized patterns and objects is so compelling that an adult makes up the border
of a white triangle that is not actually there.

The distinction the Gestaltist Edgar Rubin makes between figure (the object that
attracts attention) and ground (the background) in his analysis of visual scenes appeals
to this same ‘aboutness of the picture’. Depending on what adults take the figure or
the ground to be, he argues, adults see the famous figure 3.3 alternately as a white
vase against a black background or two black profiles against a white background. Obviously, however, there is no similar kind of visual illusion going on in figure 3.4.

(8) All cowboys are riding a horse

However, given the Principle of Pregnanz as a universal principle of “figural goodness” (Coren, Ward, and Enns, 1999:301; cf. also the meaning of the German word *Pregnanz* ‘conveying the essence of something’) which only gives rise to visual illusions in particular cases, adults are likely to perceive figure 3.4 as symmetrical as possible. Their visual “interpretation” of this picture is about the exception to a rule (i.e. one horse is not being ridden). However, in the context of a Truth-Value Judgment task and a sentence about ‘cowboys’, I take adults to reanalyze the picture and check whether or not each cowboy is riding a horse. Meroni, Gualmini, and Crain (2001) provide experimental support for such an analysis of figure 3.4. Using an eye-tracker to study the on-line processing of quantified sentences like (8) in extra-object situations, they found that adults’ eye fixation patterns reveal looks at the extra object. Crucially however, adults do not use this information in restricting
the domain in sentences like (8). In the cases in which adults mirror children’s
behavior and give answers in terms of the extra object (e.g. cups), such a reanalysis
does not take place. I take the “no, not that one”-answers in the latter case to result
from the fact that the sentence subject is conceptually associated with another set
(such as cups and saucers). This leads adults to take the picture as a leading clue
and to interpret the sentence to be about the one-to-one relation between cups
and saucers and the exception to this rule. This effect might be enforced by the
saucer without a cup which ‘pops out’ immediately. Such pop-out effects are well
established in the literature on adults’ perception of scenes as in figure 3.5 (adapted
from Coren et al., 1999); the slanted line immediately pops out due its different
primitive feature (i.e. being slanted instead of straight). In a similar way, I take the
adults’ symmetrical answers reported by Freeman et al. (1982) to be triggered by
the fact that one cup differs in one salient aspect (i.e. not having a saucer) from the
other saucers.

Donaldson and Lloyd (1974) suggest that it might be these same Gestaltist prin-
ciples of perception that also affect children’s understanding of quantified sentences.
The child, they argue, attaches more importance to the physical array than adults.
The necessary step for a child to take toward an adult understanding of quantified
sentences, they argue, is to determine the ultimate force of linguistic principles (cf.
Bucci, 1978). For children, the syntax does not play a decisive role to restrict the
quantifiers. Children allow the sentence figure and ground to be determined by the
figure or the ground of the scene. Depending on which set they take as the figure
of the visual scene, children interpret a sentence like All cowboys are riding a horse
to be either about the set of horses, the set of cowboys or the one-to-one relation
between horses and cowboys. Following Donaldson and Lloyd, I hypothesize that
children primarily use the visual information to determine what the sentence is
about. Given the apparent violation of the one-to-one relation between cowboys
and horses in the extra-object situation, the child focuses on the mismatch in the
scene and assumes the sentence to address this (cf. in this respect also the pop-out
effect discussed above). As Donaldon and Lloyd put it:
“... young children do not encode the sentence with enough regard to the structural properties of the language for this encoding to serve as a precise determinant of the object (or picture) encoding. What happens is that the sentence initially serves to delimit a set of options. (This of course is not to imply that the child explicitly considers these as separate possible interpretations.) Thereafter the direction of control is reversed and it is rather the encoding of the sentence that is contingent on the encoding of the physical array” (Donaldson and Lloyd, 1974:85)

In the next section, I will take up this suggestion and identify the hypothesis that will drive the experiments presented in subsequent chapters.

3.3 The Equilibrium Hypothesis

In the previous section, I showed that the interpretation of quantified sentences is constrained by the discourse and the visual context, in addition to the syntactic and semantics principles identified earlier. A growing body of research shows that next to syntactic information, adults use discourse context and visual context to interpret a (quantified) sentence. In line with this body of research, I hypothesize that pragmatics (discourse and visual contexts) interacts with syntax and semantics. The child is faced with the task to find out when and how each of these factors constrain the meaning of quantified sentences.

Crucially for current purposes, this interaction between syntax, semantics and pragmatics in the adult language implies that a different perspective needs to be taken on children’s acquisition of quantified sentences. Instead of focusing on the question whether or not children master the relevant syntactic, semantic and pragmatic constraints, the question needs to be asked to what extent children master the interaction between these constraints. This then leads to the following hypothesis:

(9) **Equilibrium Hypothesis:**

The acquisition of quantification is a matter of establishing a target-like equilibrium between syntax, semantics and pragmatics and their contribution to meaning

How do children restrict a quantifier domain? Or, to put it differently, how does the child’s equilibrium differ from adults’? To what extent do children attach different importance to each of the factors that play a role in interpreting quantified expressions than adults do? In the next section, I will identify three research questions that follow from (9).
3.3.1 Acquisition at the interfaces

Assuming an interaction between syntax, semantics and pragmatics as outlined above, it is at the interfaces of syntax-semantics, syntax-pragmatics and semantics-pragmatics that children are predicted to give non-adult-like interpretations. Zooming in on each of these interactions, consider, first of all, the interaction between syntactic structure and semantics, illustrated with the Dutch quantifier *allemaal* in (10). The meaning of this quantifier as either an exhaustive or a non-exhaustive quantifier depends on the syntactic construction: *allemaal* as a floated quantifier in (10-a) gets an exhaustive reading whereas *allemaal* in an existential *er* (‘there’) sentence as in (10-b) gets a non-exhaustive reading. So syntax determines the domain over which will be quantified.

(10) a. De papegaaien vliegen allemaal
   The parrots fly *allemaal*
   ‘The parrots are all flying’

b. Er vliegen allemaal papegaaien
   There fly *allemaal* parrots
   ‘There are many flying parrots’

The question arises how children interpret *allemaal*. Do they use the syntactic information or rather the information in the visual context (i.e. the picture to be judged in a Truth-Value Judgment Task) to determine what this sentence is about? In chapter 4, I take up this question.

In a similar way, the question arises whether children differ from adults in their interpretation of *many* when pragmatics interacts with the syntax to restrict a quantifier domain. Consider (11) which is true or false depending on the context provided (as illustrated in (11-a) and (11-b) respectively).

(11) Many parrots are flying
    a. Situation: 20 out of 25 parrots are flying
    b. Situation: 5 out of 25 parrots are flying, 20 out of 25 sparrows, 20 out of 25 peacocks

Children’s interpretation of *many* is the subject of chapter 5.

Finally, the question arises how children differ from adults when the syntax does not provide sufficient information to restrict the quantifier domain. Consider the second sentence in (12) for which the discourse is clearly needed to restrict the quantifier domain and hence determines the truth value of the sentence.

(12) The farmer owns several horses and a donkey. All horses are great jumpers.

The domain of *all* in the second clause in (12) is restricted to the set of horses that the farmer owns. A reading according to which all horses in the world are said to be great jumpers is incorrect. This shows that domain restriction interacts with
the discourse even when the syntax provides the quantifier domain. In chapter 6, I address the question how children integrate the discourse context into the meaning of a quantifying expression.

The hypothesis investigated is that children weigh various clues differently from adults to determine the meaning of a quantified sentence.

### 3.3.2 The Equilibrium Hypothesis in relation to previous studies

Krämer (2000) shows that children’s non-adult-like interpretation of so-called high indefinites is due to their inability to integrate the discourse. Consider example (13) (from Krämer, 2000:175): (13-a) contains a low indefinite (note its position between the adverbial and main verb) and allows both a wide-scope reading and a narrow-scope reading (i.e. *een potje* (a jar) might be either inside or outside the scope of *twee keer* (twice); (13-b) contains a high indefinite (with the NP to the left of the adverbial) and only allows a narrow-scope reading (*een potje* is outside the scope of *twee keer*).

(13)  

<table>
<thead>
<tr>
<th>a.</th>
<th>Je mag twee keer een potje omdraaien</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>You may two times a jar turn</td>
</tr>
<tr>
<td></td>
<td>‘You may turn over a jar twice’ (may involve two jars)</td>
</tr>
<tr>
<td>b.</td>
<td>Je mag een potje twee keer omdraaien</td>
</tr>
<tr>
<td></td>
<td>You may two times a jar turn</td>
</tr>
<tr>
<td></td>
<td>‘You may turn over a jar twice’ (should involve only one specific jar)</td>
</tr>
</tbody>
</table>

Children, however, also assign a wide-scope reading to (13-b) and turn over two different jars. Given an analysis of the indefinite in (13-b) as a free variable which needs a bridge with the preceding discourse to identify its accommodation site (cf. Van Geenhoven, 1998), Krämer argues that this interpretation shows that children do not integrate the discourse to interpret the indefinite in (13-b). The Equilibrium Hypothesis is compatible with these findings and, even more generally, hypothesizes that it is not only the discourse that children use differently than adults, but that the entire interplay between syntax, semantics and pragmatics characterizes children’s interpretation of quantified sentences. High and low indefinites present such cases, similarly as quantificational determiners such as *every* and *all* do.

The effect of visual context is known since Piaget who tested number conservation in children (repeated by Dehaene, 1999). He showed that children between four and six years of age, when they are asked which row out of two rows contains more elements, use the visual information to answer this question. If both rows contain the same number of elements but there is more space between the elements in the second row which is therefore longer (as in figure 3.6), children use this misleading clue and answer that this second row contains more elements. Dehaene (1997) argues that this is due to the fact that children actually understand the question to be about the length of the lines and therefore answer non-adult like. Apparently, children use visual information in a particular situation whereas adults do not.
Children’s usage of visual information in language comprehension is further illustrated by Kelly (2001). He shows that the role of non-verbal pointing and eye gaze in language comprehension extends beyond the first years of life. Children between three and five years of age show significantly more target-like behavior in complex pragmatic communication if the verbal message is accompanied with nonverbal pointing and gaze.

In sum, various kinds of data support the hypothesis that children’s non-target-like understanding of (pragmatically) complex sentences like quantified sentences might be due to an off-balance equilibrium between syntax, semantics and pragmatics. The extra-object condition used in previous experiments on quantification (see figure 3.4) probes children’s understanding of quantified sentences precisely in a situation in which these constraints compete with each other; by asking children to interpret a quantified sentence given this visual context, the child needs to apply both syntactic and visual constraints. The Equilibrium Hypothesis explains why children answer differently than adults in these situations to quantified sentences; since children attach different importance to each of the relevant constraints than adults, children judge quantified sentences differently than adults. The question to be answered is how this non-adult-like equilibrium exactly looks like. Moreover, is there a way to model the equilibrium between syntax, semantics and pragmatics and, hence, formulate precise predictions?

In the next section, I will introduce Optimality Theoretic semantics. Optimality Theory semantics (Hendriks and De Hoop, 2001) provides us with a formal framework to do so. Moreover, and crucial for current purposes, this framework allows to translate the predictions regarding children’s versus adults’ interpretations of quantified sentences to experimental settings.

### 3.4 Optimal acquisition of optimal meaning

#### 3.4.1 A short introduction to Optimality Theoretic Semantics

Optimality Theoretic semantics has its roots in Optimality Theory (henceforth OT; Prince and Smolensky, 2004). In OT, a grammar consists of a set of constraints. What is grammatical in a language, depends on how these constraints are ordered in this particular language. Acquisition is considered to be a reranking of constraints
in the target order (Smolensky, to appear). This means that a child does not understand or use language target-like until the child has ranked the constraints in the target-like order.

Crucially, constraints in OT are soft and violable. In addition, Hendriks and De Hoop’s Free Interpretation Hypothesis states that the possible interpretations of a syntactic structure are in principle infinite. However, the most harmonic or optimal interpretation is the preferred interpretation of a sentence. The interpretation whose evaluation violates the least number of constraints and/or the least important ones, ends up as the actual interpretation of a sentence. Interpretation is considered to be an optimization process with respect to a certain syntactic input. Crucially for current purposes, the constraints against which all possible interpretations are evaluated can be syntactic or pragmatic in nature. This means that it is possible to model how lexical material, syntactic structure and context play a role in the optimization process from form to meaning. Note that such an approach takes a completely different view on compositionality; it crucially allows interaction between constraints of various nature. This differs from the classical view on compositionality, i.e. the view that the meaning of an expression is a function of the meaning of its parts and of the syntactic rules by which they are combined.

The constraints used in OT are either markedness or faithfulness constraints. Whereas markedness constraints are only related to the output, faithfulness constraints are related to both the input and the (possible) output. Consider a situation in which somebody utters (14). A faithfulness constraints states that the subject of the sentence expresses the agent of the action denoted by the verb. This means that one gets the interpretation that the cowboy loves his horse and one does not get that the horse loves the cowboy.

(14) The cowboy loves his horse

An often used example of a markedness constraint is that every sentence needs to have a subject (Grimshaw, 1997).

The constraints form one component of the OT framework. Next to the set of constraints (CON), there is a mechanism that generates a set of candidates given a certain input (GEN) and a mechanism that evaluates these candidates against the set of constraints (EVAL). In OT semantics, taking a comprehension point of view c.q. hearer perspective, this means that GEN takes a form and generates a set of possible interpretations of this form. This set of possible interpretations is in principle infinite. EVAL assigns to each interpretation a constraint profile. This constraint profile codes how harmonically the interpretation satisfies the set of ranked constraints. The candidate with the highest harmony is selected as the

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5 Note that the constraints themselves are by some authors considered to be innate and universal (Prince and Smolensky, 2004) and to be learned by others (Boersma, 1998; Boersma and Hayes, 2001). For current purposes, it does not matter which position is taken.
3.4. Optimal acquisition of optimal meaning

output. For comprehension, this means that optimality can be defined as in (15) (from Blutner 2000:199-200).

(15) A form-meaning pair $(f, m)$ is a comprehension optimal iff
a. $(f, m) \in \text{Gen}$
   b. and there is no $(f, m') \in \text{Gen}$ such that $(f, m) \succ (f, m')$

In sum, in an Optimality Theoretic framework, attributing a meaning to a linguistic structure involves an optimization procedure from form to meaning. This procedure is constrained by principles of various nature (syntactic, semantic and pragmatic). How can we account for quantification, and, additionally, how can we model children’s non-target-like interpretations of quantified sentences? In the next two sections, I will address these two issues.

3.4.2 Optimal quantification

For quantification, several constraints of different nature are at play. First, there is a syntactic constraint that states that a quantifier takes its N’ as its restriction (Hendriks and De Hoop, 2001). Hendriks and De Hoop (2001) label this constraint Syntactic Structure.

(16) Syntactic Structure:
   Use the N’ to restrict a quantifier domain (Hendriks and De Hoop, 2001:22)

Second, quantified sentences with a weak quantifier like *many* illustrate that the relation the quantifier establishes between its first and second argument can be contextually restricted. What counts as *many flying birds*, for example, is clearly context-dependent, since it depends on one’s measure of comparison (see for a similar approach Krämer, 2000). This only applies to weak quantifiers like *many* and *few*. Strong quantifiers like *every* and *each* might be contextually restricted (in the case of *All boys are laughing*, all boys is contextually restricted to the set of boys in the domain of interpretation), but note that the truth conditions do not change in this respect; whether all boys are laughing still depends on whether there are

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6*Harmonic ordering* is the key concept here. This is defined in Tesar and Smolensky (1998:233) as follows (their italics):

(i.) Harmonic ordering:
   A grammar’s constraint ranking induces a harmonic ordering $\succ$ of all structural descriptions.
   Two structures $a$ and $b$ are compared by identifying the highest-ranked constraint $C$ with respect to which $a$ and $b$ are not equally marked: the candidate that is less marked with respect to $C$ is the more harmonic, or the one with higher Harmony (with respect to the given ranking).

7Alternatively, optimality can be defined in terms of optimal production (Blutner, 2000) and, even more generally, optimality can be defined without committing oneself to a speaker (production) or hearer (comprehension) perspective to language (cf. Prince and Smolensky’s original definition of optimality). However, to keep things clear and given the focus of this thesis on the interpretation of quantified sentences, I will discuss here and in the remainder of this thesis only the comprehension view.
boys that are not laughing. By making use of the distinction between weak and strong quantifiers (in the sense of Milsark, 1979), I propose the constraint Semantic Relation which captures the context-dependence of quantifiers like many: 8

(17) Semantic relation:
For weak quantifiers, use the discourse topic to select the set against the background of which the interpretation of the quantified expression needs to be determined.

Not only the measure of comparison is context dependent; the context can also restrict the quantifier's domain. Hendriks and De Hoop argue for the constraint DOAP (Don't Overlook Anaphoric Possibilities, Williams (1997)). 9

(18) Don’t Overlook Anaphoric Possibilities (DOAP) (Williams, 1997)
Make sure that anaphoric elements are related to the previous discourse.

This constraint makes sure that one interpret all for example in (19) as ‘all the rabbits that were everywhere’. 10

(19) Rabbits were everywhere. All suddenly jumped out of the magician’s hat.

A fourth constraint arises from the observations discussed above that visual context can also affect the quantifier domain. For adults, this is only the case when the syntax does not provide sufficient information (i.e. Syntactic Structure is ranked higher than Faith-Vis).

(20) Faith-Vis: Make sure that anaphoric elements are related to the theme of a picture (i.e. visually prominent items).

In (20), ‘visually prominent’ has to be understood as, for example, exceptions to a rule or generalization which stand out more than non-exceptions (cf. the Principle of Pregnanz as discussed in section 3.2.2). In the case of the classical extra object picture with one horse without a cowboy sitting on it, this horse clearly stands out as an exception and therefore is a visually prominent item. By means of Faith-Vis we are now able to account for adults’ disambiguation of sentences by means of visual information as reported by Trueswell et al. (1999); if the visual context supports an

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8See chapter 5 for a refinement on this constraint.
9Actually, DOAP is a family of constraints. I return to this issue in chapter 5 and 6 where I discuss the relevant constraints of DOAP. In chapter 6, I crucially also argue for an approach that incorporates both the family of constraints called DOAP and the constraints (with some modification) from Centering Optimality Theory (Beaver, 2004). In a similar way, I redefine Semantic Relation as a family of constraints in chapter 5.

10Note that ‘anaphoric elements’ in the definition of DOAP should be understood rather broadly. In a similar way as in (19), the sets the quantifier all relates to each other in All men love baseball is taken to be solved by means of anaphora resolution. Or, in the words of Geurts (2003:205): “a strongly quantified NP “Q X” is like an anaphoric pronoun in that it prompts a search for a contextually salient collection of Xs, which are to serve as Q’s domain.”
interpretation that does not violate any syntactic constraints, this interpretation becomes the optimal one. Moreover, it explains the findings of Meroni et al. (2001) that adults’ eye fixation patterns reveal that adults notice the horse without a cowboy on top of it in figure 3.4 when they are asked to interpret (21); adults check whether there is a visually prominent item, and seem to check whether Faith-Vis is violated or not.

Consider example (21). In OT, the meaning of a sentence is typically represented in a tableau. In an OT tableau, the top row contains the input (i.e. a sentence, represented by the example number) and then the relevant constraints in rank order. The strongest constraint is on the left, the weakest constraint on the right. The following rows display candidates, here possible interpretations, each star marking a violation of this candidate with respect to a certain constraint. The optimal candidate (indicated by ‘*’ ) is the candidate that violates the least number of constraints or the candidate that only violates those constraints that are ranked lower than the constraints violated by other candidates. Constraints that are irrelevant (for example, because they only apply when the sentence is embedded in a discourse) are marked gray. See (22) for an example.

(21) Every cowboy is riding a horse

Using these four constraints we can now account for adults’ interpretation of (21) as in (22) (in which A is the set of cowboys and B the set of horses).\[11\]

\[\begin{array}{|c|c|c|}
\hline
\text{Example (21)} & \text{Syntactic Structure} & \text{DOAP} \\
\hline
\text{Every}(A,B) & \# & \\
\text{Every}(A,B) \land \text{Every}(B,A) & \#! & \\
\hline
\end{array}\]

In (22) Syntactic Structure is violated by the second candidate since the quantifier domain contains the set of horses instead of the set denoted by the N’ (cowboys). The constraint DOAP does not apply (there is no discourse context) and is therefore marked gray. Semantic Relation does not apply either since this constraint is only called into action when the quantifier is a weak quantifier (i.e. passes Milsark’s (1979) existential there-sentence test). Faith-Vis is violated by the first interpretation.

\[\text{\footnotesize \#}\] For easiness sake, the interpretations of Every cowboy is riding a horse in this and the following tableaus are represented with Every(A,B) and Every(A,B) \land Every(B,A). Crucially, in the latter case, the domain of every is both A (the set of cowboys) and B (the set of horses).
since the visually prominent item (i.e. the horse) is not related to the quantifier’s first argument set. The first candidate ‘wins’ because it is the most optimal interpretation for (21).

Following Donaldson and Lloyd (1974) and Bucci (1978) and hypothesizing in line with the Equilibrium Hypothesis that children rank *Faith-Vis* above *Syntactic Structure*, the child’s non-target-like answer of (21) in the extra-object pictures can now be accounted for as in (23) (in which the constraints that do not apply are left out of the tableau).

![Tableau](image)

Taking the work of Donaldson and Lloyd (1974) and Bucci (1978) as a starting point that children use visual information to interpret a quantified sentence before they rely on syntactic information, *Syntactic Structure* is ranked below *Faith-Vis* in (23). The violations for *Syntactic Structure* and *Faith-Vis* are the same as in (22); it is only the child ranking that returns the interpretation of (21) as ‘All cowboys are riding a horse and all horses are being ridden by a cowboy’ as the most optimal one. Using this same ranking, it also follows that such a non-target-like answer disappears if more horses are depicted than in the classical case (i.e. 20) (see Crain et al, 1996 and Sugisaki and Isobe, 2001). In these cases the horses without a cowboy on top of it are not an exception to a generalization anymore, hence there is no visually prominent item and *Faith-Vis* is irrelevant. Since *Syntactic Structure* is violated by the non-target-like interpretation, the target-like answer is now the optimal one as illustrated in (24).  

![Tableau](image)

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One might even argue that in pictures with lots of horses, the cowboys are visually prominent and force a target-like interpretation. Note that in this case, *Faith-Vis* is only satisfied by the target-like interpretation since the quantifier’s domain is in line with the visually prominent set. Since *Syntactic Structure* is violated by the non-target-like interpretation, the target-like answer also turns out to be the most optimal one in this line of thinking.
In other cases the constraints *Semantic Relation* and *DOAP* are crucially needed to determine the most optimal meaning of a given form. Consider again example (11) and (12), repeated as (25) and (26).

(25) Many parrots are flying
   a. Situation: 20 out of 25 parrots are flying; True
   b. Situation: 5 out of 25 parrots are flying, 20 out of 25 sparrows, 20 out of 25 peacocks; False

Given the status of *many* as a weak quantifier, *Semantic Relation* applies in (25). Semantic Relation is violated by an interpretation according to which the discourse topic is not used to restrict a quantifier domain. This means that *many* gets a cardinal interpretation in a situation as described in (25-a) and the set of parrots is taken as discourse topic. If the set of flying entities is taken as the discourse topic in (25-b), this results in the opposite truth value since not many parrots are flying compared to the other flying animals. The constraint *DOAP* does not play a role here, since there is an N' to restrict the quantifier and no (discourse or visual) context to narrow down this set of parrots to a particular set introduced before this sentence (see chapter 5 for more details).

For (26), *DOAP* applies in addition to *Syntactic Structure* (and *Semantic Relation* does not, since the *all* is a strong quantifier).

(26) The farmer owns several horses and a donkey. All horses are great jumpers.

This means that the domain of *all* is restricted to the set of horses the farmer owns. An interpretation according to which all horses in the world are great jumpers is therefore ruled out. *Syntactic Structure* still makes sure that *all* quantifies over horses and not over jumpers.

In sum, by using these three constraints, we can model the aspects of interpretation of quantification discussed above (the effect of discourse and visual context). In the next three chapters, I will zoom into the effects of discourse and visual context on children’s interpretations of quantified sentences and redefine *Semantic Relation* and *DOAP* into an ordered family of constraints. Moreover, in each chapter I will explore how children use (i.e. rank) these competing constraints.

### 3.5 Summary and conclusions

In this chapter, I have argued that an adult understanding of quantified sentences involves attaching the right importance to syntactic, semantic and pragmatic constraints. I formulated the hypothesis that children’s non-adult-like understanding of quantified sentences as reported in the literature is due to a non-adult-like equilibrium between these constraints of various nature. This hypothesis led to several research questions concerning children’s interpretations of quantified sentences. I
identified three research questions that underly the research presented in the next three chapters:

1. How do children use syntactic information when the visual context competes with syntactic information?

2. How do children use pragmatics to restrict a context-dependent quantifier domain?

3. How do children integrate the discourse context when establishing the meaning of a quantifying expression?