Three Semantic Puzzles for Children

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Abstract: We connect Frans Zwarts' work on semantic theory to language acquisition. Using his theories as our framework, we show how child language presents three semantic puzzles. The first puzzle concerns children's so-called Exhaustive Pairing answers with universal quantifiers. Even though Conservativity is claimed to be a universal principle, these answers seem to violate it. The second puzzle raises the question of how easy or difficult it is to acquire the veridical and non-veridical meanings of temporal connectives 'before', 'after' and 'when' vis-à-vis their temporal interpretation. The third puzzle concerns the monotonic decreasing property of negative operator 'none of the N'.

1. The First Puzzle: Conserving Conservativity

Frans Zwarts has been instrumental in advancing the relational perspective on quantifier semantics. The original idea of this treatment of quantifier meaning goes back to Montague (1970), Lewis (1972) and Cresswell (1973), and was laid down in Barwise and Cooper's (1981) theory of generalized quantifiers. The essence of the idea is that the meanings of quantifiers, such as *all*, *no* and *some*, can be defined as relations between two sets. Zwarts' contribution lies in his accessible formulations of the truth conditions for these quantifiers and the universal semantic principles that constrain their interpretation (Zwarts 1983). This section discusses one semantic principle—Conservativity—and presents a puzzle from child language: Zwarts (1983) claimed that Conservativity holds universally in restricting the meaning of quantifiers like *all*. Yet, children seem to violate it.

1.1 Conservativity

Under the relational perspective, quantificational determiners (henceforth, quantifiers) are functors that "assign to each universe E a binary relation D_E between subsets of E" (Zwarts, 1983:37). As shown in (1) (Zwart, 1983:37), the truth conditions of sentences of the form All_EAB require that the cardinality of set A minus set B be zero. Under the relational perspective, the sentence *All farmers are feeding a donkey* describes a relation between a set of farmers A and a set of donkey feeders B. The sentence is true if the cardinality of the set of farmers minus the set of donkey feeders is zero or, in other words,

if all farmers are also donkey feeders (i.e., if A is a subset of B). Similarly, *no* requires that the intersection of farmers and donkey feeders is zero and *some* requires that the intersection is equal to or larger than one.

(1) $all_E AB$ iff $|A-B| = 0$

Set-theoretic definitions of quantifiers form a coherent semantic model that is restricted by a number of logical constraints. The aim of Zwarts' (1983) article is to "suggest a number of principles that restrict the range of admissible interpretations of natural language determiners" (1983:37). The prime principle is Conservativity (e.g., Keenan, 1981), especially the strong variant in (2) (Zwarts, 1983:38, based on van Benthem, 1984).

(2) Strong Conservativity
For every universe E and every $A,B \subseteq E$, $D_E AB \leftrightarrow D_A A(A \cap B)$

"This principle (…) states that the universe as restricted to the left-hand argument provides the relevant context (…) individuals not in A are irrelevant to the question of whether or not DAB holds in E." (Zwarts, 1983:38). What matters in the process of verifying the sentence about donkey feeding farmers is all the farmers and whether or not each of them is engaged in donkey feeding. Any other individuals in the domain—such as other kinds of donkey feeders, other donkeys without a feeder or anything else—do not figure in the verification procedure; the sentence can be verified without checking these other individuals.

If Zwarts is right, quantifiers that lack the property of Conservativity (and other constraints such as Constancy, Quantity, etc.) are predicted not to exist in any natural language. This claim implicates a theory of semantic universals: out of all the logically possible quantifier meanings, there is only a limited set of quantifiers that actually exist in natural languages (Barwise & Cooper, 1981; Zwarts, 1983; van Benthem, 1984; see Keenan & Paperno, 2012 for a recent summary).

What about child language? The aim of this section is—by discussing the role of Conservativity in child language—to identify a puzzle about how children learn quantifiers. The puzzle is inspired by children's non-adultlike responses to sentences with universal quantifiers given certain visual contexts.

1.2 Are children always conservative?

The most investigated topic in the acquisition of quantifier meaning is without doubt children's judgments of sentences with universal quantifiers with respect to so-called

Extra-Agent and Extra-Object contexts. Extra-Agent trials represented by (3) test if a child knows the exhaustivity requirement of the universal quantifiers *all*, *every*, and *each*. The target response is rejection of the sentence because of the 'extra' uninvolved agent in the context (the boy not carrying a bag). Extra-Object trials like those represented by (4) test the same requirement, but here the target response is acceptance, because each girl is indeed eating a banana. Note that the 'extra' object in the context, the banana not being eaten, due to Strong Conservativity, is irrelevant to whether or not the test sentence is true with respect to the context.

The reason why these judgments have attracted so much attention is a striking response pattern in children. They correctly respond *no* on Extra-Agent trials, showing they have acquired the exhaustivity requirement of universal quantifiers. At the same time, however, they consistently respond *no* on Extra-Object trials, motivating their answer by pointing out that the extra object is uninvolved. This latter response is alternately referred to as "Spreading" (Roeper & De Villiers, 1993), "Symmetric Answer" (Philip, 1995) and "Exhaustive Pairing" (Drozd, 2001). We will stick to the latter term here, focusing on the insight that children seem to require that the agents and objects mentioned in the test sentence be paired up.

(3) Extra Agent trial

Test Sentence:

All the children are carrying a bag.

Target: *No*.

(4) Extra Object trial

Test Sentence:

All the girls are eating a banana.

Target: *Yes*.

While Exhaustive Pairing can be traced back to the original work of the developmental psychologists Inhelder and Piaget (1964), it was Philip in his dissertation (1995) who pointed out the importance of Exhaustive Pairing for linguists, and for semanticists in particular. Philip claimed that children who make Exhaustive Pairing judgments have a problem determining the domain of quantification. For adults, the domain of a quantifier

is determined syntactically: it is the denotation of the noun phrase headed by the quantifier (i.e., the set of girls denoted by *the girls* in (4). For Philip, the children's explanations for Exhaustive Pairing responses indicate that they quantify over events rather than individuals and construe the denotations of constituents in the verb phrase (i.e., the set of bananas denoted by *a banana* in (4)) as restricting the domain of quantification.

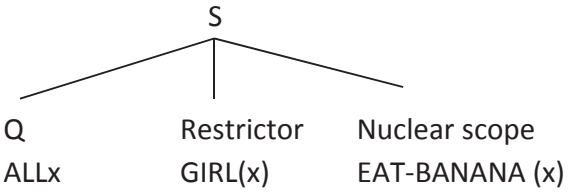
The interpretation of sentences with universal quantifiers in Extra-Object contexts have been on the linguistic research agenda ever since 1995 and continue to produce a steady stream of research output (for a recent review, see Philip, 2011). Exhaustive Pairing judgments form a crosslinguistically robust milestone in typical language development; the pattern has been established now for at least 12 languages (Drozd et al., in progress).

1.3 The puzzle: Do Exhaustive Pairing judgments obey Conservativity?

A widespread view in developmental linguistics is that Exhaustive Pairing judgments occur when the denotation of a set other than the denotation of the NP complement of a universal quantifier is construed as its domain. This violates Conservativity, which restricts the domain of a quantifier to the denotation of the quantified NP (the A-set). Only elements in the A-set are considered when verifying a universally quantified sentence. Exhaustive Pairing thus raises the intriguing semantic puzzle of whether children's interpretations of quantificational determiners are conservative, as has been claimed for adult grammars (Zwarts, 1983). Many explanations have been advanced for the Exhaustive Pairing judgment. We review some of the most prominent explanations here, and point out whether or not they are conservative.

For easy reference across the explanations below, we use the tripartite structure for quantification, with sentential positions for quantifier, restrictor (domain) and nuclear scope (Heim 1982). For our purposes, the restrictor corresponds to the domain or A-set for the quantifier, and the nuclear scope to the B-set for the quantifier. The relation between restrictor and nuclear scope is defined by Q. The tripartite structure for *All girls are eating a banana* is given in (5). This structure is conservative because only the A-set (i.e., girls) is in the restrictor.

(5)



Two explanations for Exhaustive Pairing share the assumption that children do not appropriately constrain the domain, even though they understand universal quantification and the fact that universal quantification quantifies exhaustively over a domain (Philip, 1995; Roeper & De Villiers, 1993). Where these explanations differ is in their claims about how children select domains. We now point out how both explanations do not obey Conservativity.

Roeper and De Villiers (1993) coined the term "spreading" for the Exhaustive Pairing judgment because the quantifier seems to 'spread' throughout the sentence: "a quantifier attached to one NP applies to all NP's in a clause" (1993:120). Presenting a syntactic explanation, Roeper and De Villiers argued that the quantifier does not form a NP with its nominal complement. Rather, it functions syntactically like a sentential adverb of quantification (such as *always*) which takes sentential scope. Under this explanation, children who make Exhaustive Pairing judgments construe a sentence like *Every girl is eating a banana* to mean *A girl is always eating a banana.* This explanation violates Conservativity because the determiner is restricted to events denoted by the VP predicate rather than individuals in the denotation of the NP *girl*. Elements of the B-set should be irrelevant to the question of whether the quantifier relation holds of A and B.

Philip (1995) introduced the term "symmetric answers", because Exhaustive Pairers seem to require that sentences with universal quantifiers be paired with contexts depicting symmetrical relations: all the girls must be eating and, moreover, all the bananas must be eaten by a girl too. Philip argued that Exhaustive Pairing involves quantification over events rather than individuals: *All girls are eating a banana* is true when "all minimal events which are subevents of girl-eating-a-banana event, and in which a girl or a banana (or both) is a participant, are events in which a girl is eating a banana" (Philip, 1995:69). Thus, the quantifier binds an event variable rather than an individual variable and is restricted to events involving either a girl or a banana as participants, as represented in (6).[1] Conservativity is violated, because the quantifier binds an event variable while it should bind the individual variable introduce by the NP.

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[1] The notation in (6) is a simplification of Philip's notation. Applying Philips (1995:69) to our example here:

Q	Restrictor	Nuclear scope
$\forall e_1$	$\exists e_2$ [$e_1 \leq e_2 \wedge$ eating (girl,banana,e_2) $\wedge$ PART(girl, e_1)]	a girl is eating (e_1) a banana
	or	
	$\exists e_2$ [$e_1 \leq e_2 \wedge$ eating (girl,banana,e_2) $\wedge$ PART(banana, e_1)]	

(6)	Q	Restrictor	Nuclear scope
	ALL_e	PARTICIPANT (GIRL (x,e)) or PARTICIPANT (BANANA (x,e))	GIRL-EATING-BANANA (e)

Two other explanations argue that children understand that universal quantifiers denote tripartite structures, but do not always assign universal quantifiers relational denotations when required. Instead, learners semantically represent universally quantified sentences using quantification structures associated with weak quantifiers like *two* and *many* (Drozd, 2001; Geurts, 2003). The two explanations differ as to which interpretation Exhaustive Pairers arrive at when they judge a universally quantified sentence.

Drozd (2001) points out that strong quantifiers are presuppositional; they trigger the presupposition that the quantifier's A set exists in discourse context when presented with a quantified sentence for judgment. Drozd argued that Exhaustive Pairers do not always represent the quantifier's domain as presupposed if it is not brought to their attention before they are presented with Extra Object trials, and therefore do not distinguish the domain from the nuclear scope when the test sentence is presented to them for judgment on these trials. Under these conditions, children may interpret the sentence *Every boy is riding an elephant* "…to mean 'Is the number of elephant-riding boys consistent with what speaker and hearer accept as 'every'?'" (Drozd, 2001:364). In the Extra-Object situation, the number of elephant-riding boys is smaller than the child is expecting, inviting the child to point out the elephant for which a boy is missing. This explanation also violates Conservativity because the B-set argument of the quantifier is construed as contributing to the restriction on the quantificational domain.

Fleshing out Drozd's (2001) proposal, Geurts (2003) argued that children initially assign semantic representations associated with weak quantification to process sentences with universal quantifiers, because weak quantification requires relatively simpler non-relational semantic representations and a relatively less complicated syntax-semantics mapping process. Geurts posited that Exhaustive Pairing results when things go awry in the process of mapping form to meaning. Specifically, Geurts proposed that Exhaustive Pairers initially assign a non-relational bipartite semantic structure represented by (7) to the sentence *All the girls are eating a banana*. Knowing that universal quantifiers have relational meanings, children then construct an interim tripartite structure represented by (8) which leaves the domain of quantification undetermined. Exhaustive Pairers then select denotations of sentential constituents to restrict the domain of the quantifier based on pragmatic factors. When bananas are construed as salient and topical, a child will choose the denotation of *a banana* rather than the NP *girls* to restrict the domain,

motivating an Exhaustive Pairing judgment. In this way, Geurts' account also violates Conservativity, since the denotation of a constituent other than the NP occurring with the quantifier restricts the quantifier.

(7)	Q	Nuclear scope	
	ALL	GIRL(x) $\wedge$ BANANA (y) $\wedge$ EAT (x,y)	
(8)	Q	Restrictor	Nuclear scope
	ALL	…	GIRL(x) $\wedge$ BANANA (y) $\wedge$ EAT (x,y)
(9)	Q	Restrictor	Nuclear scope
	ALL	BANANA(x)	GIRL(x) $\wedge$ EAT (x,y)

The explanations for Exhaustive Pairing we have so far reviewed all entail that Exhaustive Pairing judgments do not obey Conservativity. However, this puzzle is complicated by several factors. First, not all explanations of Exhaustive Pairing violate Conservativity (Berent, et al., 2009; Crain et al., 1996; Crain, 2000; Rakhlin, 2007). In a well-known paper, Crain et al. (1996) argued that Philip's (1995) event quantification account leads to a severe learnability problem. Crain and colleagues pointed out that children find sentences with universal quantifiers ambiguous. On some occasions, they respond like adults and can be assumed to employ grammatical interpretative options. Exhaustive Pairing judgments indicate that children also entertain other interpretations for such sentences. Since children only encounter evidence consistent with their grammatical interpretations, they will never be able to 'unlearn' the interpretation underlying the Exhaustive Pairing response and fail to converge on the adult grammar (Crain et al. 1996:108). Crain and colleagues claimed that children have no principled problem with universal quantifiers, nor Conservativity for that matter, but are prone to make Exhaustive Pairing judgments on Extra Object trials, because the contexts used in these trials make such judgments, rather than the expected adult judgments, pragmatically felicitous (see Drozd 2004 and Drozd and van Loosbroek, 1998, 2006, for an alternative view). Thus, Crain et al.'s explanation does not entail that Exhaustive Pairing judgments violate Conservativity. A second complicating factor is that Exhaustive Pairing has been reported not only for typically developing children in a variety of languages but also for deaf children and adults (Berent et al., 2009; Brooks & Sekerina, 2006) and adults with Broca's aphasia (Avrutin & Philip, 1998). These studies bring into focus not only the relevance of Exhaustive Pairing accounts for disciplines outside of language acquisition, but also the role of Conservativity in adult interpretations of universal quantification.

1.4 Conclusions

We have shown in this section how a robust judgment pattern in child language raises an intriguing semantic puzzle: Do Exhaustive Pairing judgments violate Conservativity? We have reviewed a number of explanations of Exhaustive Pairing that entail Conservativity violations. Yet, if child and adult grammars are constrained to the same degree by universal semantic constraints, these explanations cannot be right. Zwarts' (1983) research on the relational theory of quantifier meaning has been instrumental in making the logical properties of quantifier meanings and their implications for language learnability accessible to researchers in language acquisition.

2. The Second Puzzle: Acquiring the Veridicality of Temporal Connectives

Zwart's research on veridicality also gives us an interesting puzzle for language acquisition (Giannakidou & Zwarts, 1998; Zwarts, 1999). The puzzle concerns a difference between the connectives *before* and *after*. The connective *after* is veridical, i.e., the event of the embedded clause has a truth-value, because it "happened". *Before* is different in this respect. The embedded event can be non-veridical, i.e., it does not necessarily have to take place. (11a) and (11b) show this difference. The meaning for (11a) is that the house has completely burnt down when the fire brigade arrives, but that is not so clear for (11b). In that case, the firemen came in time to save the house.

(11) a. The firemen arrived after the house burned down.
b. The firemen arrived before the house burned down.

In fact, the *before*-sentence is ambiguous with respect to veridicality. It has a non-veridical reading but also a veridical reading, i.e., the house burned down anyway. Note that the "strength" of the veridicality depends on the aspectual nature of the predicate used. For (12) it is conceptually hard to get the reading that the swimmer drowned.

(12) The lifeguard got the swimmer out of the water before he drowned.

We can conclude that *before* is ambiguous between a non-veridical and a veridical reading. *After* is not and only has a veridical reading. There is another important difference between the non-veridical reading of *before* and the veridical of *after*: nonveridical events are not anchored in the real world, whereas veridical events are. On

the basis of this, we can hypothesis that *before* is potentially harder to acquire than *after*. However the opposite seems to be the case when we look at temporality.

2.1 Temporal connectives and temporality

The main function of *before* and *after* is that they order two events in time. In the order main clause first and subordinate clause second, *before* connects the events in the same order in time. For example *jump the gate* is first in the sentence and also first in the temporal order of events (13a). In other words, for the connective *before,* it holds that the event that comes first in time is mentioned first in the sentence. The opposite is the case for *after*: there is first jumping the gate and then patting the dog (13b).

(13) a. He jumped the gate before he patted the dog.
b. He patted the dog after he jumped the gate.

The order subordinate clause first and main clause second is derivationally more complex. For the examples in (14) the temporal order of events connected by *after* is reflected in the order of those events in the sentence.

(14) a. Before he patted the dog, he jumped the gate.
b. After he jumped the gate, he patted the dog.

Summarizing the facts on temporal order and the order of mention in the sentence, we observe that the temporal order of events connected by *before* is reflected in the simpler order of the clauses denoting those events. For *after*, it is not. There is in the case of *after* also the factor of the extra syntactic operation of topicalization.

2.2 Acquisition of temporal connectives

Clark (1971) studied the acquisition of *before* and *after* and focused on the natural order of events in time. For sentences such as (13), she found that children up to the age of 5 struggle more with *after* than with *before*. The order of mention and the order of events in time explain why *before* is easier.

Other researchers do not exactly support Clark's finding. Amidon and Carey (1972), for instance, found that kindergartners only took main clauses into account and neglected subordinated clauses. The children only acted out main clauses. Crain (1982), moreover, showed that children make far less errors in temporal connectives than previously

reported in the literature. Although he didn't find major differences between *before* and *after* in comprehension, he did find that young children prefer to use *when* over *before* in production.

What the above shows, is that the data is somewhat unclear. *After* might be more difficult than *before*, as Clark finds. Amidon and Carey finds that children focus on main clauses, regardless of the connective. Crain finds a preference for *when*. The connective *when* is interesting in light of veridicality and crosslinguistic difference. We will elaborate on this in the next section. But before we do, let us take stock: the acquisition studies only focused on temporality. From those studies *before* does not come out as more difficult than *after*. Probably *before* is easier when we take Clark's results. But if we take Zwart's insights for non-veridical *before* into account, *before* is more complex than *after*.

2.3 Crosslinguistic differences in temporal connectives

Crain's finding with respect to *when* is interesting because this connective has interesting parallels with *before*. *When* connects sentences that can be non-episodic. The sentence in (15) is ambiguous between an episodic reading and a non-episodic reading. On the episodic reading the event occurs once, and on the non-episodic reading the event happens habitually. In the latter case *when* actually means *whenever*.

(15) When I passed the gate, the gatekeeper opened it.

In semantic terminology, the episodic reading involves existential quantification over an event variable (in a Davidsonian sense), whereas the habitual expresses "a generalization over situations" (Giannakidou & Zwarts, 1998).

Zwarts (1999) distinguishes three language groups: English, Dutch-German and Greek-Spanish. As we have seen for English, there is only one lexical item (*when*) covering both the episodic as well as the non-episodic meaning.[2] However, languages such as Dutch (and German) disambiguate the episodic and non-episodic with two different connectives: *wanneer*[3] and *toen*. Both of these connectives mean *when*, but *wanneer* is used for a non-episodic reading (16a) and *toen* for an episodic reading (16b).

[2] English *when* is ambiguous between an episodic and the non-episodic reading. English has a non-ambiguous non-episodic connector *whenever*.

[3] The Dutch connective *als* works similarly to *wanneer*.

(16) a. Wanneer ik de poort passeerde, opende de poortwachter hem.
When-non-epis I the gate passed, opened the gate keeper it
When I passed the gate, the guard opened it'
b. Toen ik de poort passeerde, opende de poortwachter hem.
When-epis I the gate passed, opened the gate keeper it
'When I passed the gate, the guard opened it'

The Romance languages and Greek differentiate episodic and non-episodic readings by using different aspects. The imperfective is used for non-episodic readings and the perfective for the episodic ones. The examples in (17) are Spanish.

(17) a. Cuando pasaba la verja, el portero me la abrió.
when pass-IMP the gate the guard me it open-IMP
'When I passed the gate, the guard opened it for me.'
b. Cuando pasé la verja, el portero me la abrió.
when pass-PERF the gate the guard me it open-PERF
'When I passed the gate, the guard opened it for me'

On the one hand Greek has a connective *otan* 'when' that is sensitive to aspect, like the Romance languages, as shown in (18). On the other hand Greek also has two unambiguous connectives: *opote* 'when' combines only with the imperfective past and only allows non-episodic readings, (19a), whereas *tote pu* 'when' combines with the perfective past and only allows episodic readings (19b).

(18) a. Otan pernusa tin pili, tin anige o filakas
when pass-IMP.1sg the gate, it opened.3sg the guard
'When I passed the gate, the guard opened it'
b. Otan perasa tin pili, tin anikse o filakas
when pass-PERF.1sg the gate, it opened.3sg the guard
'When I passed the gate, the guard opened it'

(19) a. Opote pernusa tin pili, tin anige o filakas
When-non-epis pass-IMP.1sg the gate, it open.3sg the guard
'When I passed the gate, the guard opened it'
b. Tote pu perasa tin pili, tin anikse o filakas (perfective past)
when-epis pass-PERF.1sg the gate, it open.3sg the guard
'When I passed the gate, the guard opened it'

Summarizing, we have discussed three languages. First, English temporal clauses with *when* are ambiguous: they can have an episodic as well as a non-episodic reading. Second, Germanic languages such as Dutch and German and also Greek have two different temporal connectives which disambiguate between episodic and non-episodic readings. Third, Greek and the Romance languages use different aspects (imperfective or perfective) to disambiguate between these two readings. A summary is given in Table 1.

Language	Ambiguous connectives	Different connectives	Different aspects
English	*when*	*before* vs. *after*	
Dutch		*wanneer/als* vs. *Toen voordat* vs. *nadat*	
German		*wenn* vs. *als*	
Spanish/Italian			Imperf vs. Perf
Greek	*otan*	*opote* vs. *tote pu*	Imperf vs. Perf

Table 1: Summary of the crosslinguistic difference of connectives w.r.t. episodic and non-episodic readings.

The relevant difference between the two readings is the type of quantification. Veridical and episodic readings involve existential quantification over events. Non-veridical and non-episodic readings involve universal quantification.

2.4 An experimental paradigm for testing temporality and veridicality

The previous sections show the complicated characteristics of connectives. We distinguish three important factors: 1) the difference in veridicality of a connective; 2) the different aspectual value of the embedded verb; 3) the order of mention of the event. We need an experiment that disentangles veridicality and temporality in a natural way, separating temporal and episodic readings from veridical and non-episodic readings. Our proposal is to use a picture-selection task after stories. The story in (20) is the basis in a design with the four conditions in (21).

(20) Dit zijn Danisha en oma Sharon. Het was opa Frans zijn verjaardag en Danisha en oma hadden een mooie slagroomtaart voor het feest gekocht. Oma ging de boodschappen in de kelder opruimen. Danisha lustte heel graag taart. De taart

stond op een schaal op het aanrecht en Danisha wilde hem best opeten. Zij keek hongerig naar de taart. Toen kwam oma terug uit de kelder.
'Here are Danisha and grandma Sharon. It was grandpa Frans' birthday and Danisha and grandma had bought a nice cream cake for the party. Grandma went to the basement to clear away the other groceries. Danisha liked cake very much. The cake was on a plate on the kitchen counter and Danisha sure wanted to eat it. She looked at it full of appetite. Then grandma came back up from the basement.'

a. Oma Sharon zette de schaal in de koelkast, voordat Danisha de taart opat.
Grandma Sharon put the plate in the fridge, before Danisha ate the cake.
b. Welke schaal staat er in de koelkast?
Which plate is in the fridge?
Picture 1: Full plate
Picture 2: Empty plate

(21) Four conditions, varying the connective and the order-of-mention
a. Oma Sharon zette de schaal in de koelkast, voordat Danisha de taart opat.
'Grandma Sharon put the plate in the fridge, before Danisha ate the cake.'
b. Oma Sharon zette de schaal in de koelkast, nadat Danisha de taart opat.
'Grandma Sharon put the plate in the fridge, after Danisha ate up the cake.'
c. Voordat Danisha de taart opat, zette oma Sharon de schaal in de koelkast.
'Before Danisha ate the cake, Grandma Sharon put the plate in the fridge.'
d. Nadat Danisha de taart opat, zette oma Sharon de schaal in de koelkast.
'After Danisha ate the cake, Grandma Sharon put the plate in the fridge.'

Another possibility is to ask a when-question in (22). This question distinguishes between the temporal and the veridical reading. If the child answers *She didn't*, *because granny put the cake in the fridge*, this indicates a non-veridical reading. The answer: *at the party* indicates a temporal reading: grandma first put the cake in the fridge and then Danisha ate the cake.

(22) Wanneer at Danisha the taart op?
When did Danisha eat the cake?

This paradigm allows us to investigate the acquisition of temporal connectives focusing on their temporal and veridical properties. Such a study can show what is acquired first: temporality or veridicality.

3. The Third Puzzle: Testing Monotonicity

Frans Zwart's research on negation has been instrumental in bringing differences in logical behavior of negative expressions to the attention of linguists and formal semanticists (Zwarts 1986, 1996). This research revealed not only that languages include a heterogeneous class of negative expressions but that the occurrence of positive and negative polarity items is sensitive to the degree of negation expressed by a particular negative expression. For example, Zwarts argued for a logical typology of negative NPs based on their behavior in logical expressions like those in (23)-(26).

Monotone Decreasing / Zwarts' Minimal Negation

(23) NP wrote a book or won an award $\Rightarrow$ NP wrote a book and NP won an award.
a. $f(X \cup Y) \subseteq f(X) \cap f(Y)$
b. NP VP_1 or $VP_2 \Rightarrow$ NP VP_1 and NP VP_2.

(24) NP wrote a book or NP won an award $\Rightarrow$ NP wrote a book and won an award.
a. $f(X) \cup f(Y) \subseteq f(X \cap Y)$
b. NP VP_1 or NP $VP_2 \Rightarrow$ NP VP_1 and VP_2.

Anti-Additivity / Zwarts' regular negation

(25) NP wrote a book and NP won an award $\Leftrightarrow$ NP wrote a book or won an award.
a. $f(X \cup Y) = f(X) \cap f(Y)$
b. NP VP_1 or VP_2 = NP VP_1 and NP VP_2.

Anti-Multiplicativity

(26) NP wrote a book and won an award $\Leftrightarrow$ NP wrote a book or NP won an award.
a. $f(X \cap Y) = f(X) \cup f(Y)$
b. NP VP_1 and VP_2 = NP VP_1 or NP VP_2.

An NP is monotone decreasing if replacing NP in (23b) and (24b) makes these logical expressions valid. Using this test, *few chefs, at most one chef, none of the chefs* and *almost no chefs* are all monotone decreasing NPs. Anti-additive NPs in English form a subset of the monotone decreasing NPs and include *no chef, neither chef, none of the chefs, not a single chef,* and *no one* (Zwarts, 1996:184). As the equality in (25b) suggests, anti-additive NPs make (23b) as well as its converse NP VP_1 and NP $VP_2 \Rightarrow$ NP VP_1 or VP_2 valid. Thus, anti-additive NPs express a logically stronger type of negation than monotone decreasing NPs. Anti-multiplicative NPs, including the negated universals such as *not every* and *not all,* yield the logically valid equality in (26b). They form a subclass of the monotone decreasing NPs. The equality in (26b) shows that anti-multiplicative NPs make (24b) as well as its converse NP VP_1 and $VP_2 \Rightarrow$ NP VP_1 or NP VP_2 valid.

Of the four types of negative NPs, the anti-additive NP *None of the N* and the anti-additive quantificational determiner *every* have gained the lion's share of attention in language acquisition research (e.g., Boster & Crain, 1993; Gualmini, 2005; Crain, 2012). In one study Gualmini (2005) presented 3-5-year-old native English-speaking children with truth value judgment trials like (27). In (27), a child is asked to judge if the test sentence *None of the pirates found the jewel or the necklace* uttered by the puppet is true of a story in which one of three pirates finds the jewel and no pirate finds the necklace. A rejection by the child is interpreted as evidence that the child comprehended the monotone decreasing property of the subject NP in the sentence and drew the conjunctive inference *None of the pirates found the jewel and none of the pirates found the necklace* (see 23b). Gualmini (2005:50-55) reported that the children correctly rejected such sentences in such contexts 87% of the time, indicating that they understood that the NP *None of the pirates* is monotone decreasing.

(27) Gualmini's test of monotone decreasingness

> This is a story about an Indian who is going to shop for groceries. The Indian has heard that some pirates have been surprised stealing in a camp nearby, so he decides to hide all his things before he leaves. In particular he wants to hide three knives, a golden necklace and a jewel. He is really concerned about the jewel and the golden necklace, because he received them as a gift from a dear friend of his. He puts each object in a barrel and then leaves. After he leaves. Three pirates arrive. One pirate says "Look, an Indian camp! There is always a lot of stuff to steal in an Indian camp! I am sure we will find something valuable, like a jewel. Maybe even a golden necklace!" and he takes one of the barrels. He looks inside and finds a knife. A second pirate says: "Oh, just a knife! Well, I'll see if I can find something better. Maybe I can find a jewel, or maybe I can find a necklace." He takes one barrel, and he finds a knife. The third pirate says: Oh! You guys were not lucky at all! I am sure there is something better to steal here. I'll go now!" The third pirate takes a third barrel. When he looks inside the barrel, however, he also finds a knife. The pirates are very disappointed, and they are ready to leave because they know the Indian is about to come back. But one pirate says: "Hey, I can't believe we haven't been able to find anything better than knives. I will go back one more time and see what I can find!" He runs back to the Indian camp and he takes another barrel. When he looks inside he finds a jewel, and says: "See! I told you it was worth going back one more time! Now we can leave.

Puppet:
This was a story about an Indian and some pirates and I know what happened. Every pirate found a knife, but none of the pirates found the jewel or the necklace.

Such results have been claimed to show that that even young children have knowledge of the monotonic decreasing properties of NPs (Crain, 2012).

But there is a puzzle here. One might have reservations about accepting such a conclusion. One reservation is that monotone decreasingness is characterized by the two inferences described in (23) and (24). A more convincing demonstration of children's knowledge of monotonic decreasingness would be to show that they also make the second inference characteristic of monotonic decreasing NPs in (24b), NP VP_1 or NP $VP_2 \Rightarrow$ NP VP_1 and VP_2. This can be tested by modifying Gualmini's (27) so that the conjunctive inference is false given the story. Such a trial is given in (28).

(28) Zwart's test of monotone decreasingness

This is a story about an Indian who is going to shop for groceries. The Indian has heard that some pirates have been surprised stealing in a camp nearby, so he decides to hide all his things before he leaves. In particular he wants to hide three knives, a golden necklace and a jewel. He is really concerned about the jewel and the golden necklace, because he received them as a gift from a dear friend of his. He puts each object in a barrel and then leaves. After he leaves. Three pirates arrive. One pirate says "Look, an Indian camp! There is always a lot of stuff to steal in an Indian camp! I am sure we will find something valuable, like a jewel. Maybe even a golden necklace!" and he takes one of the barrels. He looks inside and finds a knife. A second pirate says: "Oh, just a knife! Well, I'll see if I can find something better. Maybe I can find a jewel, or maybe I can find a necklace." He takes one barrel, and he finds a knife. The third pirate says: Oh! You guys were not lucky at all! I am sure there is something better to steal here. I'll go now!" The third pirate takes a third barrel. When he looks inside the barrel, however, he also finds a knife. The pirates are very disappointed, and they are ready to leave because they know the Indian is about to come back. But one pirate says: "Hey, I can't believe we haven't been able to find anything better than knives. I will go back one more time and see what I can find!" He runs back to the Indian camp and he takes another barrel. When he looks inside he finds a jewel, and says: "See! I told you it was worth going back one more time! Then he looks inside another barrel and

finds a necklace, and says: "I can't believe it! I'm really glad I came back. Now we can leave."
Puppet:
This was a story about an Indian and some pirates. I think I know what happened. I know every pirate found a knife. And I know something else. None of the pirates found the jewel or none of the pirates found the necklace.

If children know that *none of the pirates* is monotone decreasing, they should make the conjunctive inference that none of the pirates found the jewel and the necklace. They should reject the test sentence on the grounds that one pirate found both.

Another reason for having reservations about the conclusion is that children may have performed well on Gualmini's experiment because they find conjunction easier than disjunction. If children do find conjunction easy to comprehend, it may be the case that the children in the monotonicity experiments drew the intended conjunctive inference or interpreted sentences like *None of the pirates found the jewel or the necklace* as *None of the pirates found the jewel and the necklace* independent of the monotonic properties of the matrix subject.

One way to test whether children are making conjunctive inferences because they are easy rather than because they are logically valid is to check if children can avoid making conjunctive inferences when they do not logically follow. This can be done by checking if children make conjunctive inferences associated with monotone increasing expressions with monotone decreasing expressions.

Zwarts (1996) observed that an NP is monotone increasing if that NP makes the conditionals in (28a,b) and (29a,b) valid. Monotone increasing NPs include *every N, the N, someone,* and *at least N.* Monotone decreasing NPs do not make (28b) or (29b) valid.

Monotone Increasingness

(28) NP wrote a book and won an award $\Rightarrow$ NP wrote a book and NP won an award.
  a. $f(X \cap Y) \subseteq f(X) \cap f(Y)$
  b. NP VP_1 and VP_2 $\Rightarrow$ NP VP_1 and NP VP_2.

(29) NP wrote a book or NP won an award $\Rightarrow$ NP wrote a book or won an award.
  a. $f(X) \cup f(Y) \subseteq f(X \cup Y)$
  b. NP VP_1 or NP VP_2 $\Rightarrow$ NP VP_1 or VP_2.

If children understand the monotonic decreasing properties of *none of the pirates* they should understand that the sentence *None of the pirates found a jewel and a necklace*

does not license the inference *None of the pirates found a jewel and none of the pirates found a necklace* (see 28b). The key to setting up the experiment is already given by Zwarts' (1996:177) explanation for the invalidity of his conditional *No fireman said good-bye and left* ⇒ *No fireman said goodbye and no fireman left*.

> "For if there are precisely two firemen, one of whom said goodbye without leaving and one of whom left without saying goodbye, then the antecedent of the conditional (…) is true, but its consequence false."

Integrating the logic of this example into Gualmini's trial yields the following alternative trial in (30).

(30) Zwarts' monotone decreasing test

> This is a story about an Indian who is going to shop for groceries. The Indian has heard that some pirates have been surprised stealing in a camp nearby, so he decides to hide all his things before he leaves. In particular he wants to hide three knives, a golden necklace and a jewel. He is really concerned about the jewel and the golden necklace, because he received them as a gift from a dear friend of his. He puts each object in a barrel and then leaves. After he leaves. Two pirates arrive. One pirate says "Look, an Indian camp! There is always a lot of stuff to steal in an Indian camp! I am sure we will find something valuable, like a jewel. Maybe even a golden necklace!" and he takes one of the barrels. He looks inside and finds a knife. A second pirate says: "Oh, just a knife! Well, I'll see if I can find something better. Maybe I can find a jewel, or maybe I can find a necklace." He takes one barrel, and he finds a knife. The pirates are very disappointed, and they are ready to leave because they know the Indian is about to come back. But one pirate says: "Hey, I can't believe we haven't been able to find anything better than knives. I will go back one more time and see what I can find!" He runs back to the Indian camp and he takes another barrel. When he looks inside he finds a jewel, and says: "See! I told you it was worth going back one more time! Then the second pirate says: "Hey, I'm going to try again too!". He runs back to the Indian camp, takes another barrel, and finds a necklace. He says: You're right! It was worth going back! Now we can leave."
>
> Puppet:
> This was a story about an Indian and some pirates and I know what happened. Every pirate found a knife, but <u>none of the pirates found the jewel and the necklace</u>.

If children know that *none of the pirates* is monotone decreasing, they should not make the conjunctive inference that none of the pirates found the jewel and none of the pirates found the necklace. Children should avoid rejecting the target sentence either on the grounds that one of the pirates found the jewel or on the grounds that one of the pirates found the necklace. If children find conjunctive inferences easy, they might make the conjunctive inference even though it is not licensed by monotonic decreasing NPs.

4. Conclusions

We have presented three puzzles from child language for Frans Zwarts' semantic theories. The first puzzle about Exhaustive Pairing answers has attracted a lot of attention in the L1 literature. We point out how none of the proposed explanations obeys Conservativity. Our tentative conclusion is that children's grammars are not constrained by Conservativity. But that raises the puzzle of how universal principles like Conservativity are in describing the (child) languages of the world. The second puzzle pits the (non)-veridical interpretation of temporal connectives *before* and *after* against their temporal meanings. We propose a novel experimental paradigm for testing the relative ease or difficulty of acquiring these two meaning aspects. The third puzzle asks when children acquire the monotonic decreasing property of negative operator 'none of the N'. We point out how one study in the literature may have concluded too quickly that children know it, since it tested only one of the negative monotonic inferences. We develop an experimental paradigm for testing whether children know the mirror image inference too. All in all, we believe that the way forward in studying children's acquisition semantics is to frame the issues in hard core semantic theories, such as those contributed by Frans Zwarts.

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