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Anaphora from Athens to Amsterdam

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a) Stoic syntax and the Stoic concept of anaphora

There is a thesis about syntax which is rather unpopular today. It says that logical form must be intimately connected with surface syntax of natural language. One of the protagonists of such a tenet was Richard Montague with his version of semantic syntax, which constructed syntax and semantics in a strictly parallel way. This leads to a strict form of a naturalness principle, according to which we must be prepared to treat the forms of natural language as they appear in natural language syntax without paraphrasing them away. There are constructions for which we can fulfill this requirement rather well, e.g. in the semantics of noun phrases as treated by Montague and Barwise and Cooper in their classical paper (cf. also Egli 1975). Note that the standard treatment by Frege and Russell paraphrased these noun phrase constructions with the help of more basic unrestricted quantifiers and connectives.

One of the most important topics where the naturalness principle of a natural semantics can be observed is the domain of anaphora, where some researchers have developed an alternative to the representation of anaphorically used pronouns as bound variables. A prominent example is the field of the medieval languages of logic which was popularized very early by Geach [1962]; in fact, it was Geach who first introduced versions of the medieval donkey sentences into the modern discussion [Geach 1962, 117]:

(0)   If somebody owns a donkey, he beats it.

I wish to argue that ancient discussions of sentences like (0), e.g. those of the Stoic philosophers, are important for the modern discussion of these facts in the same way as medieval Terministic reflections of these facts are. Concerning anaphora, aspects of this discussion are preserved in the writings of the technical grammarians of the time of the Roman Empire like Apollonios Dyscolos, who cite the theories of the Stoics, which for their part are no longer extant. These grammarians were reintroduced into the discussion by historical linguists

like Windisch and have since passed from the circles of historians of language into the books of synchronically working linguists.

Although we have no explicit testimony, it is not hard to infer where the Stoic theoreticians of language would have placed anaphora. The treatment of anaphora belongs to the Stoic subdivisions of the atomic sentences and the composition of more complicated sentences from atomic ones.
According to the Stoics the simple sentences were subdivided into three kinds which I shall characterize briefly:

(1)   definite sentence: this one is walking

(2)   categorical sentence: (a) man is walking
                                       (Greek without article)

(3)   indefinite sentence: somebody is walking

We call a sentence categorical if it has a subject which is an indefinite noun phrase containing a common noun: e.g., a woman, an inhabitant of Konstanz, a dog. In the Greek version of these noun phrases there is no formal expression of the indefinite article "a". In a similar way we call a sentence indefinite which has a pure indefinite quantifier that is not restricted by a common noun, e.g. somebody, something.

First, I want to translate some of the basic passages about these three types of sentences. I will give a translation which slightly paraphrases the passage from Sextus Empiricus *Adversus Mathematicos 8*, 96-100:

"Among the atomar sentences some are definite, some are indefinite, some are in the middle between them - which are called categorical in the parallel passage by Diogenes Laertios. Definite sentences are those whose deictic subject is assigned an individual, e.g. "this one is walking", "this one is sitting". For I assign a singular man to the subject. According to them indefinite sentences are those in which an indefinite particle is at the beginning, e.g. "somebody is sitting". In the middle are sentences like "a man is sitting" or "Socrates is walking". The sentence "somebody is walking" is indefinite because it doesn´t define some specific individual which is walking. For it can be said of every one of these men, whereas the sentence "this one is walking" is a definite sentence, as it defines the person assigned to the deictic subject. The statement "Socrates is sitting" is a sentence in the middle because it is neither indefinite, defining the kind; nor is it definite, with an assignment of an individual to the subject, but it seems to be in the middle of the other two kinds of sentences, the definite ones and the indefinite ones." (96-97)

A special feature of the Stoic subdivision is that the sentence "Socrates is sitting" is, like all sentences having a proper noun as subject, not counted among the definite sentences, but among the categorical sentences, something which somehow runs against the intuitions we have today. Proper nouns were thought to be a special type of common noun. Whereas according to the Stoics common nouns referred to more than one individual, or had an arbitrary set as their extension, proper nouns referred to one individual, or had a singleton as their extension. In a similar way the expression "somebody" was considered to designate a most general kind. It was considered to be a most general common noun, which referred to every individual, or which had the whole universe of discourse as its extension.

With the help of negation, which could either be placed before the whole sentence or be placed before the predicate, the Stoics obtained a version of the four kinds of simple sentences acknowledged by Aristotle, e.g. in his *De interpretatione*. In addition to the unnegated categorical sentences the Stoics got three further negated types. In a similar way in addition to the unnegated indefinite sentence the Stoics got three types of negated categorical sentences, corresponding to the four kinds of quantified sentences recognized by Frege in his *Begriffsschrift*. From an unnegated sentence like:

1. a man is just

the Stoics formed three other types of sentences by inserting or not inserting a negation at two places. This gives the Stoic version of the categorical sentences of Aristotle:

2. a man is unjust
3. it is not the case that (1.)
4. it is not the case that (2.)

Stoic:	1) A man is just	2) A man is unjust	3) It's not the case that (1)	4) It's not the case that (2)
Aristotelian:	I Some men are just	O Some men are unjust	E No men are just	A All men are just
term positive	yes	no	yes	no
positive	yes	yes	no	no
Stoic form	sp	s non-p	non sp	non s non p
Fregean form	SxK sxpx	SxK sxNpx	NSK sxpx	NSxK sxNpx

Following a medieval convention, the letters I, O, E, A denote the four categorical types of sentences. Note that the term categorical was borrowed in the Aristotelian tradition from the Stoics. Note also that for the Stoic version there were no existence presuppositions for terms.

Therefore empty and universal terms may occur freely. The variables s and p stand for the syntactical categories of subject and predicate. Like the Aristotelians the Stoics formed categorical arguments from categorical sentences, e.g.:

It is not the case that an Athenian is not a Greek; it is not the case that a Greek is not a man; therefore it is not the case that an Athenian is not a man.

The Aristotelian school version of this argument is, of course, the following:

Every Athenian is a Greek; every Greek is a man, therefore every Athenian is a man.

From simple sentences the Stoics formed complex sentences with the help of connectives like "and", which were treated semantically, at least in part, by providing the familiar truth definitions for the sentences formed with their help. An important subclass of these complex sentences is exemplified by the following example (4):

(4)   if somebody is in Athens, it is not the case that he is in Rhodes.
(5)   if Socrates is in Athens, it is not the case that he is in Rhodes.

One may compare sentence (4) with sentence (5).
In considering such sentences the following problem arises: The pronoun in sentence (5) may be explained easily in its semantic function by a theory of substitution of proper names for pronouns. It stands for the name "Socrates", because it can be replaced by this name without change of meaning. We may guess that this is the origin of the name "pronoun" for designating pronouns: pro nomine stat, the pronoun stands for a name. If I try to apply this theory to sentence (4), I quickly come to a kind of paradox for which the Stoics had a proper designation: it is the nobody paradox. Wheras in (5) the substitution yields (6a), which is semantically equivalent to (5), the substitution of "somebody" for "he" in (4) yields (6b), which is not semantically equivalent to (4).

(6a)   if Socrates is in Athens, it is not the case that Socrates is in Rhodes.
(6b)   if somebody is in Athens, it is not the case that somebody is in Rhodes.

The substitution theory of pronouns is invalid in this case. This forces us to distinguish deictic occurrences of pronouns and anaphoraical occurrences of pronouns. Previous to the discussion of these data definite pronouns were all treated as deictic - demonstrative -, but then the Stoics had to consider two uses of pronouns: deictic ones and anaphoric ones, uses referring - being anaphorically related - to an antecendent.

This state of affairs is contained in the succinct statement of Apollonios Dyscolos: Every (occurrence of) a pronoun is either deictic or anaphoric.

Of course, this is not yet the whole story about the nobody sentences. They are rather uncommon. Sentences of type (4) were called *καθολικά* by the Stoics. This means general, universal. This means that the Stoics had a version of universal sentences in the modern sense. Furthermore, this means that we may infer (5) from (4).

The nobody sentences are a simpler variant of the medieval donkey sentences. The Stoic solution of the nobody-problem consisted in the development of a theory of the truth of indefinite sentences and sentences with anaphoric pronouns which was independent of the mere substitution of nouns. There nevertheless remained a residue of the theory of substitution of anaphoric pronouns, in that deictic sentences were used to explain the truth of the corresponding indefinite sentences, as we shall see.

In developing a theory of indefinite sentences and anaphora the Stoics invented a variant of predicate logic, in addition to the propositional logic contained in their theory of syllogisms, as they used both constants going beyond propositional logic, as well as predicate and subject variables in the form of demonstratives in their texts, e.g. in the passage on negation by Alexander of Aphrodisias *In Anal. Pr.* 404ff.

Let me clarify this by commenting on a second example of a nobody-sentence, the example (7). The Stoics contended that it was logically equivalent to the example (8):

(7)   If somebody is born under the Dog Star, he can not be drowned in the sea.
(8)   It is not the case, that somebody is born under the Dog Star and that he can be drowned in the sea.

Thus, the Stoics saw the possibility of transforming sentences with anaphora relationships. In such transformations the new sentence also had anaphora relationships, characteristically related to those of the original sentences.

The syntax of modern predicate logics, which is based on the four Fregean principles of logical syntax, differs in essential ways from Stoic syntax. For Stoic syntax the Fregean principles must be reformulated in order to account for the special flavor of the Stoic version of logical notation.

The four principles of Frege

1 .   atomic sentences vs. subject-predicate sentences

      predicate and argument vs. definite, categorical, indefinite

2 .   iterative composition by formation rules

      connectives: "and" "not"
      quantifiers: "of somebody it can be said that "

3.   Raising of the quantifiers
      obligatory vs. facultative

      "of somebody it can be said that" vs. "somebody"

4.   Binding within the syntactical scope vs. Binding outside of it

The first principle concerning predicate-argument structure of atomic sentences is replaced in the discussions of the Stoics by the theory of simple sentences acknowledging the definite, categorical and indefinite sentences just explained.

Second, the thesis of iterative composition of complex sentences by formation rules using the connectives "not" and "and" as well as quantifiers like "it can be said of somebody that" is anticipated in the Stoic version of formation rules, their syntax of complex sentences.

Third, the Stoics already applied a theory of raising of quantifiers from their occurrence in situ in natural language sentences. A sentence like "a man is walking" can be rendered as "it can be said of a man, that he is walking". Such formulations are attested in the Introduction to Logic of Galen. The Stoics used two equivalent formulations, though, as Cicero *De Fato* and Alexander of Aphrodisias show: They could formulate sentences like "There is somebody who is walking" or "there is somebody and he is walking". Raising of quantifiers is obligatory in modern notations of predicate logic, whereas in Stoic syntax it is an optional, logically equivalent way of expressing the propositions.

Scope

Sentence without raising:
Somebody is in the garden and he walks

Sentence with raising and independent second conjunct:
Of somebody it can be said that he is in the garden, and he walks.

Sentence with raising and dependent second conjunct:
Of somebody it can be said that he is in the garden and that he walks

Scope = that-sentence after the quantifier phrase
"of somebody it can be said that"

Forth, the impossibility of binding outside of syntactical scope in modern syntax of classical predicate logic must be contrasted with the Stoic permission to bind outside of the syntactic scope. In Fregean syntax a sentence like "Somebody is in the garden and he is walking" must be transformed into "Of someone it can be said that he is in the garden, and he is walking", which in turn must be transformed into "Of someone it can be said that he is in the garden and that he is walking". In this formulation both pronouns lie within the scope of the quantifier phrase "Of someone it can be said that..." These transformations are obligatory. In Stoic syntax these transformations are optional and there exist three different ways to formalize the original sentence, all of which are logically equivalent to one another.

Having compared the principles of modern predicate logic with the Stoic way of analysing the examples within Stoic syntax, I would like to introduce modern techniques of exposition like coindexing of pronouns and equivalent use of bound variables and comment upon the examples by using these techniques. The examples are inspired by sentences occurring in Cicero´s *De Fato* in an argument which uses Stoic logic rather than giving an exposition of it:

(9a)   Fabius dies.
(9b)   Of Fabius$_i$ it can be said that he$_i$ dies.
(9c)   There is Fabius, who dies.
(9d)   There is Fabius$_i$ and he$_i$ dies.
(10a)   Somebody dies.
(10b)   Of somebody$_i$ it can be said that he$_i$ dies.
(10c)   There is somebody who dies.
(10d)   There is somebody$_i$ and he$_i$ dies.
(11a)   S p
(11b)   S$_i$ e$_i$ p
(11c)   Sx$_i$ F(x$_i$)

(12a)   If somebody$_i$ is in Athens, he$_i$ is not in Rhodes.

(12b)   Of somebody$_i$ it can be said that if he$_i$ is in Athens, he$_i$ is not in Rhodes.

(12c)   Of nobody$_i$ it can not be said truly that if he$_i$ is in Athens, he$_i$ is not in Rhodes.

(13a)   C Sx$_i$ F(x$_i$) G(x$_i$)

(13b)   Px$_i$ C F(x$_i$) G(x$_i$)

(14a)   Somebody$_i$ is born under the Dog Star and he$_i$ cannot be drowned in the sea.

(14b)   Of nobody$_i$ it can be said that he$_i$ has been born under the Dog Star an that he$_i$ cannot be drowned in the sea.

(14c)   If somebody$_i$ is born under the Dog Star, he$_i$ cannot be drowned in the sea.

According to the Stoics (14c) is the contrary of (14b).

The sentences (9a) and (10a) show the form of the categorical sentences without raising, whereas the sentences (9b) and (10b) show the raised form of the sentences (9a) and (9b). In transformational grammar this transformation is called quantifier raising, though the details differ from the form used here (cp. May 1985).

The formulas under (11) show the symbolization of sentences of type (10) with the help of the constant for "somebody", as in Egli (1979), of the symbol e for "he" and with the help of the syntactic predicate variable p.

The indices of the constants S and e, or the typographic form of the variable x, respectively, show the anaphora relationships between occurrences of the pronouns and the quantifiers of the sentence.

Sentences of type (12) are the $\kappa\alpha\theta o\lambda\iota\kappa\acute{\alpha}$ of the Stoics mentioned before, i. e. the Stoic formulation of universal sentences, where (12b) is a form similar to the standard formalization of these universal conditionals in modern predicate logic with a raised quantifier, which is moreover conventionally expressed with a form meaning "every".

(13) shows the formalization of these sentences in the dynamic predicate logic of Groenendijk and Stokhof and in standard classical predicate logic, which goes back to Frege. Note that in formulation (13a) dynamic binding or anaphora relationships obtain between the quantifier in the antecendent and the variable in the consequent, whereas the binding or anaphora relationship in sentence (13b) is static, because the variables lie in the so called syntactic scope of the quantifier, whereas in (13a) this is not the case for G(xi), but only for F(xi).

The sentences under (14) show an important relationship between conjunctions with positive last conjunct and implications with negated consequent, which is the contrary of the last conjunct of the conjunction, where anaphora relationships are conserved under equivalent transformation. The example is found at Cicero in *De Fato* 12-15 (Long & Sedley 1987, 232:38E, SVF2.954, FSD473, 989).

The Stoics had a theory of objects which conserved subject predicate structure and subdivided the predicate in a second step into an incomplete, two-place predicate and a noun phrase. By introducing such structures the Stoics made a great step beyond pure monadic predicate logic into the realm of polyadic predicate logic.

(Plato   (Dion (is seeing) $_i$P) $_c$P)S

iP   = incomplete predicate
cP   = complete predicate
S   = sentence

The recognition of polyadicity and of binding, including dynamic binding, took Stoic logic beyond Aristotelian categorical syllogistic logic and arguably made it equivalent to modern predicate logic.

b) On Stoic methodical arguments

A syntactical theory of anaphora was put to use by the Stoics in (1) formulating arguments whose validity depended crucially on the structure of anaphora relationships or binding relationships, and (2) by creating semantic theories which could be used to justify the validity of these arguments.

An argument, according to the Stoics, is e.g. "if it is day, it is light; but it is day, therefore it is light." In order to indicate the form of these arguments they used variables "If p, then q; but p; therefore q." An even more general form is "p, but q, therefore r." An argument of this form is valid in the sense of the Stoics if the negation of the conclusion forms an inconsistent text together with the premises. Thus, the argument mentioned above is valid, if "p and q and non r" is an inconsistent text.

A	valid		invalid
A 1		perantic	
B	methodical	unmethodical	
B1		unmetho- dically valid	
C	syllogistic	unsyllogistic	
C1		quasi- syllogistic	

methodical = valid in dynamic predicate logic
syllogistic = valid in propositional logic
perantic (valid) = valid in the material sense

Now the Stoics distinguished several forms of validity. First, there were the perantic arguments that were valid in the most general sense. Then there were the syllogistic arguments and the methodical arguments. Every kind of validity had coordinated kinds of invalidity and of consistency and inconsistency. I now go on to discuss the question where those arguments that were valid in the sense of dynamic logic found a place in the Stoic system. Some of these arguments were called categorical, but categorical arguments formed only the Aristotelian part of these arguments of Stoic predicate logic.

The place of predicate logic was in the treatment of what the stoics called $\mu\epsilon\theta o\delta\iota\kappa o\iota$. These arguments are marked by the essential occurrence of predicates, quantifiers, and the binding of pronouns to quantifiers. They are valid in the sense of predicate logic, whereas, as has been known since Lukasiewicz and Mates, syllogisms are arguments belonging to propositional logic which contain only propositional variables and connectives in an essential way. They are the contrary of unmethodical arguments, which contain unmethodically valid arguments as an important part, and thus are still valid in the material sense of being perantic. Together with the

methodical arguments, these form the valid arguments in the largest sense, the so called perantic arguments ($\pi\epsilon\rho\alpha\nu\tau\iota\kappa\omicron\acute{\iota}$). The syllogisms are but part of the methodical arguments. Methodical arguments which are not syllogistic were probably called quasisyllogistic ($\acute{\upsilon}\pi\omicron\sigma\upsilon\lambda\lambda\omicron\gamma\iota\sigma\tau\iota\kappa\omicron\acute{\iota}$).

The method of derivation of methodical arguments is $\grave{\alpha}\nu\acute{\alpha}\lambda\upsilon\sigma\iota\varsigma$, i.e. a complete system of classical propositional logic which is presupposed also in Stoic predicate logic, as we have seen. On the other hand, there existed the method of $\mu\epsilon\tau\acute{\alpha}\lambda\eta\psi\iota\varsigma$, which is attested by Alexander of Aphrodisias at APr. 404ff. (FDS 921, cp. Egli 1986). Metalepsis consists in a raising principle which had several special cases. One such special case is the principle T, i.e. the passage from p to "p is true"; another such case is the passage from "Fabius dies" to "of Fabius it can be said that he dies". Furthermore the system contained the possibility to extend the scope of the raised quantifier phrase from one conjunct to the whole conjunction. These possibilities of paraphrasing extended the logical validities acknowledged by the Stoics beyond the realm of propositional logic. Futhermore, the validity of the existential inference from "Fabius dies" to "someone dies" and/or the attested inference from "if someone dies, he doesn´t breathe any more" to "if Fabius dies, he doesn´t breathe any more" must be presupposed as a part of the Stoic system. One may compare the Stoic discussion of the $\kappa\alpha\theta\omicron\lambda\iota\kappa\acute{\alpha}$ and of the $\omicron\mathring{\upsilon}\tau\iota\varsigma$, the nobody paradox.

Thus, the components of the deductive system of Stoic dynamic logic that are used as an interpretation hypothesis for ancient logic are found in the ancient texts. The main texts are found in Galen´s Introduction to logic, in the commentary on Aristotle´s Prior Analytics by Alexande of Aphrodisias, in the eighth book against the mathematicians by Sextus Empiricus, and in Cicero´s book *De Fato*. A passage from Cicero´s *De Fato* runs as follows:

Hoc loco Chrysippus aestuans falli sperat
Chaldaeos ceterosque divinos neque eos usuros
esse coniunctionibus, ut ita sua percepta pro-
nuntient:
„Si quis natus est oriente Canicula,
is in mari non morietur",
sed potius ita dicant:
„Non et natus est quis oriente Canicula,
et is in mari morietur".
O licentiam iocularem! Ne ipse incidat in Dio-
dorum, docet Caldaeos, quo pacto eos exponere
percepta oporteat. Quaero enim, si Chaldaei ita
loquantur, ut negationes infinitarum coniunc-
tionum potius quam infinita conexa ponant,
cur idem medici, cur geometrae, cur reliqui
facere non possint?

Let me sketch further how this interpretation hypothesis can be used for the interpretation of ancient texts. Three methods lead to the extension of Stoic propositional logic to Stoic predicate logic. The first is the method of verifying the validity of arguments of propositional logic, the so called $\dot{\alpha}\nu\dot{\alpha}\lambda\upsilon\sigma\iota\varsigma$, which contains a complete method of doing propositional logic (cp. Egli 1983). The $\mu\epsilon\tau\dot{\alpha}\lambda\eta\psi\iota\varsigma$ is the method of paraphrasing sentences which extends valid arguments of propositional logic to predicate logic (cp. Egli 1986 on Alexander of Aphrodisias 404ff.). Sextus Empiricus tells us about a third method in Adversus Mathematicos 8. 98.-100, which I want to comment upon. This method consists in a semantic reduction of indefinite sentences to definite, deictic sentences, which helps to justify the inference of existential generalization and the inference of ecthesis - the inference from "someone p" to "this$_i$ p" with a new index i. By this index a new individual is introduced. Let me give the passages of Sextus in a slightly paraphrasing translation:

"Of the following sentences - "this one is walking", "this one is sitting" we say that they are true, if the individual which is assigned to the deictic pronoun by the deictic assignment function is denoted by the predicate." (100)

"They say that the indefinite sentence becomes true, if the corresponding definite sentence can be recognized as being true, viz. the sentence "this one is sitting" or "this one is walking". If no individual is sitting, the indefinite sentence "someone is sitting" cannot be true." (98)

c) On the systematic reconstruction of Stoic anaphora logic

In modern times, there has been a persistent tendency to repudiate the reconstruction of the Stoic theory of anaphora as a kind of binding theory. Neale (1990), for example, called the idea "unilluminating". But since about 1989 we possess a model theoretic characterisation of these constructions in the form of dynamic predicate logic, which we owe to Groenendijk and Stokhof (1991).

The language and logic A (=language and logic of anaphora) in Egli 1979 (Appendix 2) may be viewed as a formulation of a proof theoretic counterpart of this logic, whose completeness can be proved by the methods of Groenendijk and Stokhof.

The system A is formulated in a two dimensional notation which we would better translate into a notation which is nearer to the one Groenendijk and Stokhof use. The translation may be summarized in the following way:

Egli 1979

a. Argument before predicate

b. Polish notation with S for Sigma

c. Bounded quantfiers lowered as arguments

d. Quantifier raising ("left detachment") as an alternative formulation

e. Indexed pronouns (e) instead of variables

f. Binding indicated by + in a line beneath the formula

g. Pronoun (d) as definite article

h. Connectives as predicate functors

i. Dynamic relative sentence

k. Ambiguity of the predication for the representation of genericity

l. Separation of the indication of scope from sequential order

Examples

"an f is a g and it is h"

Sx_1 K K fx_1 gx_1 hx_1

K Sx_1 K fx_1 gx_1 hx_1

K S f g e h

   +   +

 d_i f g

 "the$_i$ f is g"

K e_i f e_i g"

 "he$_i$ is f and he$_i$ is g"

Note that quantifier raising is called left detachment in the article and that the term "exportation" is used for indicating the extension of the scope of the quantifier from one conjunct to the whole conjunction.

The equivalence rules in Egli (1979) are not intended to be Chomskyan syntactical transformations, as the critique by Heim (1982) seems to suppose, but rather to be transformation rules in the sense of Carnap, which extend the realm of logical truths (e.g. of the system in Egli 1974 or Church 1940) beyond the realm of static binding to the realm of dynamic truths. In a way, they can be formulated more clearly by the technique of the star function indicating the static normal form.

Star-function:

(1) $(p \wedge q)^* = r^* \wedge (s^* \wedge q^*)$ if $p = (r \wedge s)$
(2) $(p \wedge q)^* = \exists x (f(x)^* \wedge q^*)$ if $p = (\exists x (f(x))$
(3) $(p \wedge q)^* = p^* \wedge q^*$ else
(4) $(\exists x\ fx)^* = \exists x\ (fx)^*$
(5) $(\neg p)^* = \neg (p)^*$

Instead of a Hilbert type system which was intended in Egli 1979 I shall give a system of analytical tableaux in the sense of Evert Beth and Raymond Smullyan. In this system the development of the tree by the rules of predicate logic is combined with the piecemeal calculation of the static normal form.

Tree-System for dynamic predicate logic:

(i) $\underline{(\neg \exists x\ \varphi)^*}$ $\underline{(\exists x\ \varphi)^*}$
           $\neg\ \varphi^*\ (x/t)$ $\varphi^*\ (x/c)$ c new

(ii) $\underline{(\neg\ \varphi)^*}$ $\underline{(\neg\neg\ \varphi)^*}$
           $\neg\ (\varphi)^*$ φ^*

(iii) $\underline{(\neg)\ (\exists x\ \chi \wedge \psi)^*}$ (iv) $\underline{(\ \forall x\varphi)^*}$
           $(\neg)\ \exists x\ (\chi \wedge \psi)\ ^*$ $\neg\ (\ \exists x\neg\varphi)^*$

(v) $\underline{(\neg)\ ((\varphi \wedge \chi) \wedge \psi)^*}$
           $(\neg)\ (\varphi \wedge (\chi \wedge \psi))^*$

(vi) $\underline{(\varphi \rightarrow \psi)^*}$
           $(\neg\ (\varphi \wedge\neg\psi))^*$

(vii) $\underline{(\varphi \wedge \psi)^*}$
             φ^* else
             ψ^*

(viii) $\underline{(\neg\ \varphi \wedge \psi)^*}$
           $\neg\varphi^* \mid \neg\ \psi^*$

Groenendijk & Stokhof (1991) use a dynamic conjunction and a dynamic existential quantifier, in the same way as they occur in my reconstruction of Stoic logic. With Groenendijk &

Stokhof, and counter to Egli 1979, negation and universal quantification are not considered dynamical in this system, though a tree system could be defined which would conserve these properties of the system of Egli 1979.

In a way, the tree system also gives an alternative semantics for the dynamic predicate logic in the tradition of the truth value semantics of Hughes Leblanc. It can be proved equivalent to the system of Groenendijk and Stokhof.

Excavating the prehistory of dynamic predicate logic in the Stoic theory of methodical arguments makes us aware of an interrupted tradition, in a way that is possible only by philological reconstruction and the use of similar facts independently invented in modern times. That such interrupted traditions can become important has been shown by the use of ancient temporal logic and its resurrection in Kripkes semantics of modal logic. Kripke combined Prior´s reconstruction of the Diodorean system of time-logical modality with ideas from Carnap on modal logic in order to get his semantic characterization of the Lewis systems of modal logic. Modern developments offer scholars of classical logic a modern foil that can help them to understand ancient texts and to see interesting developments in them which otherwise would be incomprehensible. The modern representatives of this tradition also gain an advantage from such research, in that they can build on a tradition which helps to strengthen confidence in the new methods.

The adherents of Stoicism gave their logic high priority, saying that if the Greek gods had a logic, then it must be that of Chrysippus. As we have seen, this logic was a form of dynamic predicate logic. It is equivalent to classical predicate logic and contains it as the static part. Classical predicate logic is according to Hilbert´s thesis a privileged form of logic, and according to Quine it is the right regimentation of language. Perhaps the Stoic saying was not so false after all. But we can also learn something about our own form of predicate logic, classical and dynamical, because the Stoic developments can be considered as a finalized whole. Even if the Stoic version of dynamic predicate logic is no logic of the gods, it still is an important logic for human beings.

Bibliography

Hans von Arnim. Stoicorum Veterum Fragmenta. 4 Bde. Wiederdruck Stuttgart, Teubner, 1964.

J. Bacon. The completeness of a predicate-functor logic. Journal of Symbolic Logic 50, 1985, 903-926.

M. Baldassarri. La logica Stoica. Testimonianze e frammenti. Testi originali con introduzione e traduzione commentata. Bd. 1ff. Como, Noseda, 1984ff.

J. Barwise & R. Cooper. Generalized quantifiers and natural language. Linguistics and Philosophy 4, 1981, 159-219.

E. W. Beth. The Foundations of Mathematics. 2. Aufl. Amsterdam, North-Holland, 1968. (Studies in Logic and the Foundations of Mathematics)

A. Church. A Formulation of the Simple Theory of Types. Journal of Symbolic Logic 5, 1940, 56-68.

U. Egli. Ansätze zur Integration der Semantik in die Grammatik. Kronberg/ Taunus, Scriptor, 1974. (Forschungen Linguistik und Kommunikationswissenschaft 3)

U. Egli. The Stoic Concept of Anaphora. In: Rainer Bäuerle & Urs Egli & Arnim von Stechow (eds.), Semantics from different points of view. Berlin, Springer, 1979. (Language and Communication 6)

U. Egli. The Stoic Theory of Arguments. In: Rainer Bäuerle & Christoph Schwarze & Arnim von Stechow (eds.) Meaning, Use, and Interpretation of Language. Berlin, De Gruyter, 1983.

U. Egli. Stoic Syntax and Semantics. Historiographia Linguistica 13, 1986, 281-306.

U. Egli. Neue Elemente im Bild der stoischen Logik. In: K. Döring & T. Ebert (Hrsg.). Dialektiker und Stoiker. Zur Logik der Stoa und ihrer Vorläufer. Philosophie der Antike Bd. 1. Stuttgart, Franz Steiner, 1993.

U. Egli & R. Bäuerle. Anapher, Nominalphrase und Eselssätze. Konstanz, Universität Konstanz/SFB 99, 1985.

P. Th. Geach. Reference and Generality. 2. Aufl. Ithaca, Cornell University Press, 1962.

J. Groenendijk & M. Stokhof. Dynamic Predicate Logic. Linguistics and Philosophy 14, 1991, 39-100. (Vorversion Amsterdam, ITLI/University of Amsterdam, 1989.)

I. Heim. The semantics of definite and indefinite noun phrases. PhD University of Massachusetts 1983. Ann Arbor, University Microfilms, 1983.

I. Heim. E-Type Pronouns and Donkey Anaphora. Linguistics and Philosophy 13, 1990, 137-177.

L. Henkin. Completeness in the Logic of Types. Journal of Symbolic Logic 15, 1950, 81-91.

K. Hülser (ed.). Fragmente der stoischen Dialektik. 4 Bände Stuttgart, Frommann-Holzboog, 1987-1988. (FSD)

H. Leblanc. Truth-value Semantics. Amsterdam, North-Holland, 1976. Appendix, Notes toward a History of Truth-value Semantics, S. 293 - 302.

H. Leblanc. Alternatives to First-Order Seamntics. In: D. Gabbay & F. Guenthner (eds.). Handbook of philosophical logic. Vol 1 Dordrecht, Reidel, 1983.

A. A. Long & D. Sedley. The Hellenistic Philosophers. 2 vol. Cambridge, Cambridge University Press, 1987.

R. May. Logical Form. Its Structure and Derivation. Cambridge/Mass., MIT Press, 1975. (Linguistic Inquiry Monograph 12)

R. Montague. Formal philosophy. Ed. R.H. Thomason. New Haven, Yale Univ. Press, 1974.

R. Muskens. Anaphora and the Logic of Change. In: J. van Eijck (Ed.). Logics in AI. Berlin, Springer, 1991, 412-427. (Lecture Notes in Artificial Intelligence 478)

S. Neale. Descriptions. Cambridge/Mass, MIT Press/Bradford Book, 1990.

B. Partee. Nominal and Temporal Anaphora. Linguistics and Philosophy 7, 1984, 243-286.

R. Smullyan. First-Order Logic. Berlin, Springer, 1968. (Ergebnisse der Mathematik und ihrer Grenzgebiete 43)

A. von Stechow. ε-λ-kontextfreie Sprachen. Ein Beitrag zu einer natürlichen formalen Semantik. Linguistische Berichte 34, 1974, 1-33.