Logique & Analyse **185–188** (2004), 217–226

QUESTIONS AND LOGICAL ANALYSIS OF NATURAL LANGUAGE: THE CASE OF TRANSPARENT INTENSIONAL LOGIC

MICHAL PELIŠ*

Abstract
First, some basic notions of transparent intensional logic (TIL) are introduced. Secondly, it is studied how natural-language interrogatives are analyzed in TIL.

1. *Introduction*

The following facts point at the existence of a mutual influence relation between logic and natural language:

(1) Logicians are inspired by phenomena of natural language.
(2) Natural language is analyzed by logical means.

Although many logicians study formal systems which depart drastically from natural language, they still remain interested in the relationship between *expression* and *meaning* (*syntax* and *semantics*). For example, in the 1930s Alfred Tarski made the semantics of formal languages formally similar to the corresponding syntactical structures, by showing how mathematics can be used in semantical studies.

Now, Intensional Logic is a group of logical systems presented as staying faithful to the mutual influence relation of logic and natural language.

The first inspiration can be found in Frege's distinction between *sense* and *reference*.[1] In the following schema (*the triangle of reference*) an *expression* refers to (denotes) a *reference* (*Bedeutung*) and has a *sense* (*Sinn*). Later on,

*This paper was presented at *8th Flemish-Polish workshop on Adaptive and Erotetic Logic and their Application to the Philosophy of Science* (Zielona Gora, November 20.-22., 2003). The work was supported partially by the Foundation for Polish Science and partially by grant GACR 401/03/H047. I want to thank Hans Lycke for checking the language and style of the previous version of this paper.

[1] Frege's well known "morning and evening star"–paradox in his *Über Sinn und Bedeutung* (1892).

Carnap introduced the terms *extension* and *intension*,[2] of which extension is often understood as an expression's reference to an "object" of the real world, while the intension of an expression is understood as "something like its conceptual content" ([1], p. 14). Briefly put, the sense is *how* an expression refers to an "object".

$$\begin{array}{lcccc} \text{EXPRESSION} & \longrightarrow & \texttt{Bedeutung} & \text{"object"} & \text{EXTENSION} \quad (E) \\ & \searrow & & \uparrow & \\ & & \texttt{Sinn} & \text{"sense"} & \text{INTENSION} \quad (I) \end{array}$$

Carnap's approach meant the starting point for bridging the gap between the semantics of natural and formal languages. But, beside Frege and Carnap, also Montague's approach to the logical analysis of natural language is widely known. In the 1970s, Richard Montague created his Intensional Logic for the analysis of "some aspects of English language". In it, every expression refers to an extension, but in some cases, it can also refer to its intension. The intension is a relativization of an extension to possible worlds[3] (see [1], chapter 6).

2. *Transparent Intensional Logic*

Transparent intensional logic (TIL) was founded and developed by the Czech logician Pavel Tichý (1936–1994). In Tichý's opinion, the semantics are primary to the syntax, in that the latter can only be understood by means of the former (see [9], p. 11). Tichý worked on his logical analysis at about the same time Montague did, and although they approached the subject matter in a similar way, they worked independent of each other. Because both systems use lambda abstraction and the theory of types, the main difference is to be situated in the reference of an expression. In contrast to Montague's "case intensionality", Tichý's expressions (always) "refer" to their intensions. The word "always" is in parentheses because there still are some terms whose meaning is not dependent on possible worlds. In particular, a *non-empirical* (esp. mathematical) expression has the same extension in every possible

[2] R. Carnap. *Meaning and Necessity*. University of Chicago Press, 1947.

[3] The term *possible world* can be found already in Leibniz's works. Later on, it was used for the formalization of the semantics of some non–classical logics.

world. It is also useful to mention that proper names (construed as "labels") are understood in a non-empirical way[4] (see [5], p. 22).

In sum, an intension is denoted by an expression. But, is it necessary to introduce anything like *sense*?

Let us take an easy mathematical example: applying the function *plus* to 3 and 5. $(3 + 5)$ refers to the number 8 but in *another way* than $(6 + 2)$. The *construction* of the "object" 8 differs in both cases.

The term *construction* is important in TIL. Construction shows the structure of a term, and consequently, *how* it refers to its intension. So, for TIL, we have the following triangle of reference:[5]

$$\begin{array}{ccccc} \text{EXPRESSION} & \longrightarrow & \text{INTENSION} & & (E*) \\ & \searrow & \uparrow & & \\ & & \text{CONSTRUCTION} & & (I*) \end{array}$$

The meaning of an expression is a complex entity, it should be seen as a structure. Intensions and constructions cooperate in the formation of meaning.[6]

TIL works by means of four *basic types*: ι, o, ω, τ. The type ι is the type of *individuals* (members of the universe, resp. domain). From a model-theoretical viewpoint, the set of individuals is shared by all possible worlds. The type o is the type of the truth values: *true* and *false*. The type ω stands for possible worlds and the type τ for real numbers alias time points. In the temporal version of TIL, intensions are understood as a relativization of extension to possible worlds and time points (possible worlds with chronology). If $\alpha, \beta_1, \ldots, \beta_n$ are types, then the set of all (partial) functions with the domain $\beta_1 \times \ldots \times \beta_n$ and the range (included in) α is a type. This type is denoted by $(\alpha\beta_1 \ldots \beta_n)$. Let α be any type. Then the intensions can be defined as $((\alpha\tau)\omega)$-objects and we will denote them with the term "$\alpha_{\tau\omega}$-object".

Constructions[7] are already mentioned because of their importance for "structured meaning", but for our present purpose we need to introduce them

[4] We omit the philosophical problems and discussions about the role of expressions in the position of proper names. Some remarks can be found in [5] (pp. 27–28), [1] and [4]. We will understand every proper name as referring to an individual object which is the same in every possible world (and time). Proper names are "connected" with "naked" individuals.

[5] This is only a rough schema, for a more detailed discussion see [5].

[6] TIL's *hyperintensionality* lies in this connection between constructions and intensions.

[7] This term is used already in [7]. In the 1980s a full development in TIL was made.

in some more detail. First, atomic constructions are variables which construct objects dependent on valuations. Secondly, when X stands for any object or construction, then complex constructions are:

(1) *trivialization*, ${}^0X$, constructs just X,
(2) *composition*, $[XX_1 \dots X_n]$, constructs the value of the function construed by X on arguments construed by $X_1, \dots, X_n$ (dependent on a valuation). If there is no object construed by this construction, we call it an improper construction,
(3) *closure*, $[\lambda y_1 \dots y_n X]$, constructs the function known from the lambda calculus (dependent on a valuation).

Let us again use our previous mathematical example. Numbers are τ-objects and $[{}^0{+}({}^0 3, {}^0 5)]$ is a τ-construction of a τ-object (a number). $[{}^0{+}(x, y)]$ is a τ-construction (dependent on the valuation) of a τ-object. A construction corresponding to the function *plus* is the following $(\tau\tau\tau)$-construction $[\lambda xy[{}^0{+}(x, y)]]$, which is the same construction as ${}^0{+}$.

Tichý always emphasized TIL's *transparency*. His approach to logic was inspired by Frege who saw "logic as a language".[8] Meanings are stated by the shape of the expressions. They are "transparent" by their form ([9], p. 17).

What is, according to Tichý, the main subject of research in logic?

> Logic is the study of logical objects, individuals, truth-values, possible worlds, propositions, classes, properties, relations and the like and of ways such objects can be constructed from other such objects. ([7], p. 275)

In TIL this can be done quite successfully. Its success stems from the solutions it generates for some problems of logical analysis (for example, the meaning of the existence-predicate, believe sentences, "offices") and from its less complicated formalism in comparison with Montague grammar.

Example: "office". Let us use an "office example" to illustrate how TIL works in intensional contexts. The term *the Czech president* is an "office"–term. There is at most one ι-object (individual) holding this office in every possible world (and time). Now, compare the following two sentences:

John met the Czech president. (1)

John wants to be the Czech president. (2)

[8] The other approach is represented by Hilbert. In his case we can speak of "logic as a calculus".

In accordance with what was stated on page 219 the proper name *John* (J) is of the ι-type. The office *the Czech president* (P) is of the type $\iota_{\tau\omega}$. The words *meet* (M) and *want to be* (W) express binary relations. The first one expresses the relation between two ι-objects, J and a holder of the office P (dependent on a possible world and time). The construction can be written as:

$$\lambda w \lambda t[^0 M_{wt}(^0 J, ^0 P_{wt})]$$

with M of the type $(o\iota\iota)_{\tau\omega}$.

Sentence (2) lets us suppose that John wants to be the holder of the office. The relation W holds between a ι-object and an office ($\iota_{\tau\omega}$-object). The meaning of this sentence "holds" independent of a possible world and time. There is W of the type $(o\iota\iota_{\tau\omega})_{\tau\omega}$ in the construction of sentence (2):

$$\lambda w \lambda t[^0 W_{wt}(^0 J, ^0 P)].$$

3. *Questions*

We do not want to talk about the various logical approaches to the analysis of questions. Nice overviews can be found in [3], [10] and [2]. In the sense of our first section, we will distinguish two basic approaches:

(1) Questions and answers are studied as they are entailed in a formal system. Natural language and reasoning only play a role as the source of inspiration. In the very center of interest are common logical properties (inference, conclusion, calculus, etc.).

(2) Questions and answers are seen as part of a language (natural or formal) and the logical analysis studies how to grasp them in an established (formal) system.

TIL can be a member of 2. Its position is often called *radical reductionism* (see [10] and [3]), which is in accordance with Tichý's words:

> The need for a special logic of questions, (...), is no greater than the need for a special logic of beliefs, for a special logic of conjectures, of wishes, prayers, prejudices, promises, or insult. ([7], p. 275)

From the viewpoint of logical analysis of natural language, Tichý claims that a question and its answer share a similar logical analysis. There is no difference on the level of the semantics, only in the relation among speakers. So, the difference can only be found on the level of pragmatics (see [7], pp. 275–276).

A logical analysis of natural language has to discover the "meaning" of questions. Remark that it is necessary to distinguish a question and an interrogative sentence, because one question can be expressed by more then

"10pelis"
2005/7/18
page 222

one interrogative. The "meaning" is hidden behind the interrogatives.[9] How to discover this "semantical core"? By looking at the adequate answers (remember that these share a similar logical analysis with the questions they are an answer to). An adequate answer should be *possible* and *just-sufficient*, it does not bring less or more information than it is required to do.

3.1. *Examples of Empirical Interrogatives*

The semantical core of empirical interrogatives is an intension (of type $\alpha_{\tau\omega}$) and an adequate answer brings a value (of type α) in an (actual) world w at time t, i.e., an extension.

o-interrogatives. Following sentences are examples of o-interrogatives as well as of yes-no questions.

Does John smoke? (3)

Does the Czech president smoke? (4)

By asking a yes-no question, we are interested in a truth value, i.e., an o-object, in an (actual) world w at time t. The corresponding formulas of the logical analysis are for (3)

$$\lambda w \lambda t[{}^0S_{wt}({}^0J)]$$

and for (4)

$$\lambda w \lambda t[{}^0S_{wt}({}^0P_{wt})],$$

where S is of the type $(o\iota)_{\tau\omega}$, a class of smokers (dependent on a possible world and time). The same formulas would be used for TIL's logical analysis of *John smokes* and *The Czech president smokes*, respectively.

All yes-no questions are o-interrogatives. If the set of adequate answers to a yes-no question is $\{A, \neg A\}$, the semantical core is A which is valid or not in a w at t.

ι-interrogatives. For this type of interrogatives, the very meaning of their answers is to find a ι-object, an individual for a w at t. Usually, such a

[9] The logical form given to questions by an analysis of natural language need not be suitable for a representation in artificial intelligence (see [7], p. 282). See for example the formulas in the next section.

question is looking for the holder of an office, for example

Who is the Czech president? (5)

with logical analysis

$$^0P.$$

Another type of questions requires to choose *the only* ι-object for a w at t. Let us have the question

Who smokes, John or Tom? (6)

which means, more specifically, *Who is the only smoker, John or Tom?* In its analysis below, the trivialization sign is omitted in order to make the formula more readable:[10]

$$\lambda w \lambda t(\iota x)[S_{wt}(x) \wedge ((x = J) \vee (x = T))]$$

$o_{\tau\omega}$-interrogatives. The following question is quite similar to sentence (6):

Is it either raining or snowing? (7)

But, an adequate answer must now choose one from two statements (propositions), i.e., an $o_{\tau\omega}$-object for a w at t.

$$\lambda w \lambda t(\iota p)[p_{wt} \wedge ((p = r) \vee (p = s))],$$

where r and s are propositions of the type $o_{\tau\omega}$ and p is a variable for propositions.

Sentence (7) is a *whether-question*. All questions which need to express a proposition in their answer as an "object", belong to this category, for example

What is John's favorite proposition? (8)

or

Why is there life on Earth? (9)

[10] We will use the infix notation and omit the sign of trivialization in all long formulas. The expression (ιx) means "the only x" and ι is called the *singularizer*.

$o\iota$-interrogatives. This class includes questions whose response requires a collection of individuals (ι-objects). For example, a list of all smokers (in a w at t) for the question

Who smokes? (10)

The analysis is similar to the one of sentence (5), namely ${}^0S$. Of course, this category is open for questions with a one-member set of ι-objects as well. Some types of *which-*, *what-* and *who-questions* belong to this category. Other ones can be ι-interrogatives.

3.2. *Interrogative Attitudes*

From the above it should be clear that in TIL we are not able to recognize interrogative sentences because the semantical core is not a question. As a consequence, the difference between interrogatives and indicatives becomes a matter of pragmatics.

Some erotetic logics understand the asking of a question as an attempt at gaining new information. TIL enables one to analyze the word *ask(s)* as a relation between a questioner(s) and a semantical core. Consider the following two sentences:

John asks who the Czech president is. (11)

John asks whether Tom smokes. (12)

In the sentence (11) "asks" expresses the relation between a ι-object and an office, i.e., a $(o\iota\iota_{\tau\omega})_{\tau\omega}$-type, while in sentence (12) it states the relation between a ι-object and a proposition, i.e., a $(o\iota(o_{\tau\omega}))_{\tau\omega}$-type.

A similar analysis can be found for other attitudes, for example for

John asserts ... (13)

John knows ... (14)

John believes ... (15)

4. *Final Remark*

Transparent intensional logic can hardly be seen as friendly toward the development of erotetic logic. However, also TIL can contribute to the natural-language analysis of interrogatives.

I have tried to show that TIL's "philosophical" background had to lead to the rejection of erotetic logic as a special (new) kind of logic. From TIL's viewpoint, questions are always seen as embedded in natural language and a possible analysis should respect the significance of interrogatives on the level of pragmatics. However, some aspects of natural-language interrogatives can be studied by TIL, e.g., presuppositions of questions, but TIL is a bit cumbrous when it comes down to discovering the right logical form. This is a handicap for TIL's transmission into a group of purely formal systems which have no fixed connection with natural language.

Michal Peliš
Department of Logic
Faculty of Philosophy, Charles University
nám. J. Palacha 2
116 38 Prague 1, Czech Republic
E-mail: michal.pelis@ff.cuni.cz

REFERENCES

[1] L.T.F. Gamut. *Logic, Language, and Meaning.* The University of Chicago Press, Chicago, 1991. Volume 2: Intensional Logic and Logical Grammar.

[2] J. Groenendijk and M. Stokhof. Questions. In J. van Benthem and A. ter Meulen, editors, *Handbook of Logic and Language*, pages 1055–1125. Elsevier, Amsterdam, 1996.

[3] David Harrah. The Logic of Questions. In D. Gabbay and F. Guenthner, editors, *Handbook of Philosophical Logic*, volume 8, pages 1–60, Kluwer, 2002.

[4] S.A. Kripke, *Naming and Necessity*. Harvard University Press, 1999. Eleventh Edition.

[5] Pavel Materna, *Concept and Objects*. Acta Philosophica Fennica, Helsinki, 1998. Volume 63.

[6] Pavel Materna and Jan Štěpán, *Filozofická logika: nová cesta*. Univerzita Palackého v Olomouci, Olomouc, 2000.

[7] Pavel Tichý. Questions, Answers, and Logic. *American Philosophical Quarterly*, 15 275–284, 1978.

[8] Pavel Tichý. *The Foundation of Frege's Logic*. Walter de Gruyter, 1988.

[9] Pavel Tichý. *O čem mluvíme?* Filosofia, Praha, 1996.
[10] Andrzej Wiśniewski. *The Posing of Questions: Logical Foundations of Erotetic Inferences.* Kluwer, 1995.
[11] Andrzej Wiśniewski. Questions and Inferences. *Logique & Analyse*, 173–174–175, pages 5–43, 2001.