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JON BARWISE'S PAPERS ON NATURAL LANGUAGE SEMANTICS

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§1. Introduction. For most of the 1980s, Jon Barwise focused much of his research in the area of natural language semantics. This article surveys his research publications in that area.

Most, but not all, of those publications were in the area of situation semantics, a new approach to natural language semantics Barwise developed jointly with his colleague John Perry in the first half of the 1980s. That work was both blessed, and cursed, by becoming closely identified in academic circles with the award of a $23 million gift to Stanford from the System Development Foundation for the establishment in 1983 of its Center for the Study of Language and Information (CSLI). The development of situation semantics, and in due course its underlying mathematical foundation Situation Theory, carried out for the most part within the framework of CSLI's STASS research group (Situation Theory and Situation Semantics), was actually a relatively small part of the overall research program at CSLI. But because Barwise and Perry were leading figures at CSLI, were centrally involved in securing the SDF gift, and were respectively the first and second directors of CSLI, a general impression sprung up that the two of them had been awarded millions of dollars to develop situation semantics.

A major consequence of this false impression was that from the theory's early days, a great deal of interest was shown in the project. With so many accomplished scholars pouring over the work while the ink was still wet on the manuscript pages, Barwise and Perry were able to take advantage of a broad range of helpful criticism (even if it was not always given with a view to being helpful). This meant that they were able to develop the new theory much more rapidly than would otherwise have been the case.

But the false impression about the funding was as much a curse as a blessing, maybe more so. First, it created totally unrealistic expectations as to what the situation semantics could achieve, and what it could achieve in a short time.

Second, the rapid rate of adjustments and changes Barwise and Perry made to the theory in response to the many critiques gave rise to an equally

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false impression that there was little overall forward progress. (In their 1985 paper *Shifting Situations and Shaken Attitudes*, Barwise and Perry wittily acknowledged the unusual circumstances surrounding the theory's development by introducing the fictitious metric unit the *perwise*, defined to be the slowest rate at which a theory can change while still staying ahead of its critics.)

While intense research on situation theory and situation semantics largely dried up during the second half of the 1990s—arguably because the problems encountered seemed largely intractable given our current knowledge—its influences can be seen in various other linguistic theories and in a number of attempts to handle context, indexicality, and partiality in studies of communication, decision making, and information processing.

Because situation semantics changed so much during the ten years or so of its initial development, in writing this summary I decided not to trace each individual step. Rather, I will outline briefly the theory *as it had settled down by the early 1990s* (roughly coincident with the appearance of my own book ***Logic and Information***, written to provide a snapshot of situation theory and situation semantics at that time). Then I will provide a short annotated guide to the papers themselves. The reader interested in the historical development of Barwise's thinking can follow that development by consulting the papers in their chronological order.

From a mathematical viewpoint, arguably the biggest shift during the course of the theory's development was in moving away from viewing situation semantics as a synthetic theory, which sought to build up a mathematical framework for natural language semantics from the ground up, using the tools of set theory, to an analytic one, that takes situations as fundamental entities in the world and seeks to analyze them and construct the semantics in terms of those real objects themselves, rather than mathematical constructs that model them. Situation theory was the name Barwise and Perry gave to the mathematical analysis of situations and the various other constituents of situation semantics. This shift in approach is particularly clear in Barwise's papers *The Situation in Logic–II: Conditionals and Conditional Information* and *The Situation in Logic–III: Situations, Sets and the Axiom of Foundation*, both published in 1985, and Barwise refers to the shift explicitly in his 1987 article *Recent Developments in Situation Semantics*. (But note that from the very beginning, Barwise and Perry were adamant that the situations, relations, and so forth on which their theory was based were real objects, not mathematical constructs; the shift that took place during the 1980s was in the nature of the mathematical framework used to *represent* those objects.)

When Barwise felt that he had taken the mathematical development of situation theory and situation semantics as far as he could, he shifted his attention to other, more general issues that had arisen during the course of the investigation, namely the fundamental nature of information, how it arises, and how it is processed and transmitted. Since that work (much of it carried out with Jerry Seligman) can no longer be reasonably classified as research into natural language, it falls outside of the scope of this survey.

§2. **Contents and organization.** For the purposes of this summary, I have found it convenient to divide Barwise's papers on natural language semantics into three categories: papers on situation semantics, other papers on mathematical linguistics, and papers where the main focus is on semantic issues of language, thought, and information. There is considerable overlap and influence between many of the papers in the first and third categories. (The second category consists of just two papers, one of them written jointly with Robin Cooper.) The papers cover a time span of nine years, from 1980 to 1989. Not included in this survey, but important for a scholar who wishes to trace Barwise's thinking on natural language, are his two books ***Situations and Attitudes***, written jointly with John Perry and published in 1983, and ***The Liar: An Essay on Truth and Circularity***, written with John Etchemendy and published in 1987. Some of Barwise's later writings on information and information flow, both papers and books, investigate ideas that arose from his earlier work on situation semantics, but are outside the realm of natural language, and hence are not addressed here. I have tried to ensure that I have included all Barwise's papers on natural language semantics, but in the absence of a definitive list there is a possibility that I have missed one or two. Here is my list.

Situation semantics.

1980 *The Situation Underground*, with John Perry, ***Stanford Working Papers in Semantics***, vol. 1, edited by J. Barwise and I. Sag, Stanford Cognitive Science Group 1980, Section D, pp. 1–55.

1981 *Semantic Innocence and Uncompromising Situations*, with John Perry, ***Midwest Studies in Philosophy VI***, edited by P. A. French, T. E. Uehling, Jr. & H. K. Wettstein, University of Minnesota Press, pp. 387–403. (Also published in ***The Philosophy of Language***, edited by A. P. Martinich, Oxford University Press, 1985, Chapter 30.)

1981 *Situations and Attitudes*, with John Perry, ***Journal of Philosophy***, vol. 78, no. 11, pp. 668–691.

1981 *Scenes and Other Situations*, ***Journal of Philosophy***, vol. 78, no. 7, pp. 369–397. (Reprinted in ***The Philosophers Annual V***, edited by D. Boyer, P. Grim & J. Sanders, Rowman & Littlefield, 1982; also reprinted in Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes, 1988, Chapter 1.)

1981 *Some Computational Aspects of Situation Semantics*, in ***Proceedings of the 19th Annual Meeting of the ACL***, Association for Computational Linguistics.

1983 *Information and Semantics*, ***Behavioral and Brain Sciences***, vol. 6, p. 65.

1985 *Shifting Situations and Shaken Attitudes, An Interview with Barwise and Perry*, ***Linguistics and Philosophy***, vol. 8, no. 1, pp. 105–161. (Also published as CSLI Report No. CSLI-84-13, 1984.)

1986 *Review of* ***Inquiry***, by Robert C. Stalnaker (Bradford Books, MIT Press), in ***The Philosophical Review***, vol. 95, no. 3, pp. 429–34.

1987 *Recent Developments in Situation Semantics*, ***Language and Artificial Intelligence***, edited by M. Nagao, North Holland, pp. 387–399.

1989 *Model-Theoretic Semantics*, with John Etchemendy, ***Foundations of Cognitive Science***, edited by M. Posner, MIT Press, 1989, pp. 207–243.

1989 *Situations and Small Worlds*, in J. Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989, Chapter 4. (Also published in German translation as "Situationen und kleine Welten", in ***Semantik***, edited by A. von Stechow & D. Wunderlich, de Gruyter, 1991, pp. 80–89.)

1989 *Situations, Facts, and True Propositions*, in J. Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989, Chapter 10.

1989 *Notes on Branch Points in Situation Theory*, in J. Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989, Chapter 11.

Mathematical linguistics.

1980 *Generalized Quantifiers and Natural Languages*, with Robin Cooper. ***Linguistics and Philosophy***, vol. 4, no. 2. pp. 159–219. (Also published in ***Stanford Working Papers in Semantics***, vol. 1, edited by J. Barwise and I. Sag, Stanford Cognitive Science Group 1980, Section 68 V.I, pp. 325–385.)

1986 *Noun Phrases, Generalized Quantifiers and Anaphora*, in ***Generalized Quantifiers: Linguistic and Logical Approaches***, edited by E. Engdahl and P. Gärdenfors, Reidel Studies in Language and Philosophy.

Logic, thought, and information.

1984 *The Situation in Logic–I: Logic, Meaning and Information*. CSLI Report No. CSLI-84-2. (Also published in ***Proceedings of the VII International Congress for Logic, History, and Philosophy of Science, Salzburg, 1983***, North Holland, 1984, and in ***Logic, Methodology and Philosophy of Science VII***, edited by B. Marcus et al., Elsevier, 1986, pp. 183–203, and as "Logic and Information", Chapter 2 of Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989.)

1985 *The Situation in Logic–II: Conditionals and Conditional Information*, CSLI Report No. CSLI-85-26. (Also published in ***On Conditionals***, edited by E. C. Traugott, C. A. Ferguson, & J. S. Reilly, Cambridge University Press 1986, and as Chapter 5 of Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989.)

1985 *The Situation in Logic–III: Situations, Sets and the Axiom of Foundation*, CSLI Report No. CSLI-85-26. (Also published in ***Proceedings***

of the 1984 Logic Summer School, edited by A. Wilkie et al., North Holland 1986, and as Chapter 8 of Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989.)

1986 *Information and Circumstance*, ***Notre Dame Journal of Formal Logic***, vol. 27, no. 3, pp. 324–338.

1987 *On the Circumstantial Relation between Meaning and Content*, ***Versus***, vol. 44, pp. 23–39. (Also published in ***Meaning and Mental Representations***, edited by U. Eco, M. Santambrogio & P. Violi, Indiana University Press, pp. 23–40, and as Chapter 3 of Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989.)

1987 *Unburdening the Language of Thought*, ***Mind and Language 2***, pp. 82–96.

1988 *The Situation in Logic–IV: On the Model Theory of Common Knowledge*, CSLI Report No. CSLI-88-122. (Also published as Chapter 9 of Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989.)

1988 *Three Views of Common Knowledge*, ***Theoretical Aspects of Reasoning about Knowledge, II***, edited by M. Vardi, Morgan Kauffman, pp. 365–379.

1990 *Information, Infons, and Inference*, with John Etchemendy, ***Situation Theory and Its Applications***, vol. 1, edited by R. Cooper. K. Mukai & J. Perry, CSLI Publications, pp. 33–78.

§3. Situation semantics: the very idea. Situation semantics starts by taking seriously (and aggressively) the naïve assumption that since people use natural language to talk about the world—to provide information about the world in the case of utterances of declarative sentences, for example—a semantic theory should address that *aboutness* in a fundamental way. This marks re-adoption of a view common prior to the work of Frege in the late 19th Century that was abandoned when significant problems were encountered in trying to construct a rigorous and formal account of *aboutness*. Picking up a phrase used by Donald Davidson, Barwise and Perry described their development of situation semantics as an attempt to recover "our pre-Fregean semantic innocence."

The Barwise–Perry collaboration began in large part with Barwise's interest in partial structures and partial information and Perry's concern with what they came to refer to as the efficiency of language—the ability of (the same piece of) language to carry different information depending on the context.

The basic idea behind situation semantics is that people use language in limited parts of the world to talk about other limited parts of the world. Call those limited parts of the world *situations*.

For Barwise, approaching natural language semantics from his background in the branch of mathematical logic known as model theory, a semantic theory based upon the situation that a particular utterance is about clearly represented an attempt to treat natural language in a similar way to the familiar Tarski semantics of predicate logic, whereby a well formed formula of predicate logic is, with an appropriate assignment of objects to the variables, interpreted in a mathematical structure.

In their 1980 paper *The Situation Underground*, Barwise and Perry say of situations:

> "The world consists not just of objects, or of objects, properties and relations, but of objects having properties and standing in relations to one another. And there are parts of the world, clearly recognized (although not precisely individuated) in common sense and human language. These parts of the world are called situations. Events and episodes are situations in time, scenes are visually perceived situations, changes are sequences of situations, and facts are situations enriched (or polluted) by language."

They continue:

> "Situations are ubiquitous. By the very nature of things we cannot escape being in situations. It is situations which we perceive and talk about. In the more developed part of human language there are even singular terms that designate situations:
>
> Jone's sleeping in his cell
> Scott's writing of ***Waverly***
> Utah's having twenty-nine counties
> The cat's being on the mat
> John's situation
>
> There are predicates suited to such terms:
>
> was embarrassing
> distressed Henry
> was not expected
>
> And there is pronominal reference to situations:
>
> Jone's sleeping in his cell was embarrassing but it didn't distress Henry
> Scott's writing of ***Waverly*** was fortuitous since it gave Russell a good puzzle.
>
> Since the terms that designate situations are typically nominalizations of sentences, a very natural idea is that simple declarative sentences generally designate situations, with more complex sentences indicating properties of, or relations between, situations."

The authors acknowledge that Austin was a strong proponent of this situational view of language, and like him they decide eventually to base their situation semantics on statements (i.e., utterances of sentences) rather than sentences themselves. The idea that sentences (or statements) designate situations was also considered by Russell, Wittgenstein, and Reichenbach. But, by and large, it was ignored by most 20th century philosophers and logicians working on formal semantics, who (following Frege) viewed sentences primarily as bearers of truth.

Not surprisingly, situations and situation-types (which classify situations according to various similarities) figured large in Barwise and Perry's early work on situation semantics. But as the theory developed, attention shifted more to what they called constraints, the connections between types that give rise to the flow of information. This gave rise to a considerable amount of technical work on the nature of the objects of the theory called parameters. Ultimately, it was the pursuit of the role played by constraints that led Barwise away from natural language semantics and into the realm of information flow in general.

§4. Situation theory and situation semantics–vintage 1992. The early development of situation semantics was guided by a number of observations in addition to the importance of situations.

First, at a more general level, there was a clear acknowledgement that *partiality* must be embraced and taken account of. Situations are *parts* of the world and the information an agent has about a given situation at any moment will be just a *part* of all the information that is theoretically available. This contrasted situation semantics from the get-go with possible worlds semantics, seen by many as the principal competing theory against which situation semantics should be compared and contrasted.

Second, Barwise and Perry adopted a stance of *realism*. Although they did a fair amount of mathematical modeling, particularly in their early work on situation semantics, they always assumed that situations were real, actual parts of the world and that the basic properties and relations the theory dealt with were real objects, uniformities across situations (and not bits of language, ideas, sets of n-tuples, or functions).

A third fundamental idea was the *relational theory of meaning*. According to this theory, the meaning of an expression ϕ is taken to be a relation

$$d, c\|\phi\|e$$

between an utterance or discourse situation d, a speaker's connection function c, and a described situation e.

The key notion of constraint, which played a major role in later work, was not present explicitly in the early work on situation semantics.

Basic ontology of situation theory.

In situation theory, information is always taken to be information *about* some situation, and is taken to be in the form of discrete items known as *infons*. Infons are of the form

$$\ll R, a_1, \dots, a_n, 1 \gg, \quad \ll R, a_1, \dots, a_n, 0 \gg$$

where R is an n-place relation and $a_1, \dots, a_n$ are objects appropriate for R.

During the initial development of situation semantics, Barwise and Perry used a different notation; the $\ll \ldots \gg$ notation started to come into use some time after 1985. The invented word "infon" was introduced by me in the late 1980s; prior to that Barwise and Perry used the term *state of affairs* (sometimes abbreviated to SOA).

The class of *compound infons* is constructed from the infons by closing under operations of conjunction and disjunction and bounded existential and universal quantification (over parameters).

Infons (or compound infons) are 'items of information'. They are not things that in themselves are true or false. Rather a particular item of information may be true or false about a situation.

Given a situation, s, and an infon σ, write

$$s \models \sigma$$

to indicate that the infon σ is 'made factual by' the situation s. Read this as *s supports* σ.

The claim $s \models \sigma$ is referred to as a *proposition*.

The objects (called *uniformities*) in the ontology include the following.

- *individuals*, denoted by $a, b, c, \ldots$
- *relations*, denoted by $P, Q, R, \ldots$
- spatial *locations*, denoted by $l, l', l'', l_0, l_1, l_2, \ldots$
- *temporal locations*, denoted by $t, t', t_0, \ldots$
- *situations*, denoted by $s, s', s'', s_0, \ldots$
- *types*, denoted by $S, T, U, V, \ldots$
- *parameters*, denoted by $\dot{a}, \dot{s}, \dot{t}, \dot{l}$, etc.

The agent-relative framework that 'picks out' the ontology is referred to as the *scheme of individuation* (appropriate for a study of that agent *vis á vis* information flow).

The intuition is that in our study of the activity (both physical and cognitive) of a particular agent or species of agent, we notice that there are certain regularities or *uniformities* that the agent either individuates or else discriminates in its behavior.

Relations are structured objects that have (in particular): *appropriateness conditions* and *minimality conditions*.

The *basic types*:

- TIM: the type of a temporal location
- LOC: the type of a spatial location
- IND: the type of an individual
- REL^n: the type of an n-place relation
- SIT: the type of a situation
- INF: the type of an infon
- TYP: the type of a type (see later)
- PAR: the type of an *parameter* (see later)
- POL: the type of a polarity (0 and 1)

For each basic type T other than PAR, there is an infinite collection $T_1, T_2, T_3, \ldots$ of *basic parameters*, used to denote arbitrary objects of type T.

The parameters T_i are sometimes referred to as T-*parameters*.

Notation: $\dot{l}$, $\dot{t}$, $\dot{a}$, $\dot{s}$, etc. to denote parameters (of type LOC, TIM, IND, SIT, etc.).

Given an object, x, and a type, T, we write

$$x : T$$

to indicate that the object x is *of* type T.

An *anchor* for a set, A, of basic parameters is a function defined on A, which assigns to each parameter T_n in A an object of type T.

If σ is a compound infon and f is an anchor for some of the parameters in σ, $\sigma[f]$ denotes the compound infon that results from replacing each parameter $\dot{a}$ in $\mathrm{dom}(f)$ by $f(a)$.

Restricted parameters are constructed as follows.

Let v be a parameter. A *condition* on v is a finite conjunction of infons. (At least one conjunct should involve v, otherwise the definition is degenerate.)

Given a parameter, v, and a condition, C, on v, define a new parameter, $v \upharpoonright C$, called a *restricted parameter*. $v \upharpoonright C$ denotes an object of the same type as v, that satisfies the requirements imposed by C (*in any situation where this applies*). (If C consists of a single parametric infon σ, we write $v \upharpoonright \sigma$ instead of $v \upharpoonright \{\sigma\}$.)

Let $r = v \upharpoonright C$ be a parameter. Given a situation s, a function f is said to be an *anchor* for r in s if:

1. f is an anchor for v and for every parameter that occurs free in C;
2. for each infon σ in C: $s \models \sigma[f]$;
3. $f(r) = f(v)$.

There are two kinds of type-abstraction, leading to two kinds of types.

Situation-types. Given a SIT-parameter, $\dot{s}$, and a compound infon σ, there is a corresponding *situation-type*

$$[\dot{s} \mid \dot{s} \models \sigma],$$

the *type* of situation in which σ obtains.

This process of obtaining a type from a parameter, $\dot{s}$, and a compound infon, σ, is known as *(situation-) type abstraction*. The parameter $\dot{s}$ is called the *abstraction parameter* used in this type abstraction.

For example,

$$[SIT_1 \mid SIT_1 \models \ll \text{running}, \dot{p}, LOC_1, TIM_1, 1 \gg].$$

Object-types. These include the basic types TIM, LOC, IND, REL^n, SIT, INF, TYP, PAR, and POL, as well as the more fine-grained uniformities described below.

Object-types are determined over some initial situation.

Let s be a given situation. If $\dot{x}$ is a parameter and σ is some compound infon (in general involving $\dot{x}$), then there is a type

$$[\dot{x} \mid s \models \sigma],$$

the *type* of all those objects x to which $\dot{x}$ may be anchored in the situation s, for which the conditions imposed by σ obtain.

This process of obtaining a type $[\dot{x} \mid s \models \sigma]$ from a parameter, $\dot{x}$, a situation, s, and a compound infon, σ, is called *(object-) type abstraction*.

The parameter $\dot{x}$, is known as the *abstraction parameter* used in this type abstraction.

The situation s is known as the *grounding* situation for the type. In many instances, the grounding situation, s, is the world or the environment we live in (generally denoted by w).

For example, the *type* of all people could be denoted by

$$[IND_1 \mid w \models \ll \text{person}, IND_1, \dot{l}_w, \dot{t}_{now}, 1 \gg].$$

Again, if s denotes Jon's environment (over a suitable time span), then

$$[\dot{e} \mid s \models \ll \text{sees, Jon}, \dot{e}, LOC_1, TIM_1, 1 \gg]$$

denotes the type of all those situations Jon sees (within s).

This is a case of an object-type that is a type of situation.

This example is not the same as a *situation-type*. Situation-types classify situations according to their internal structure, whereas in the type

$$[\dot{e} \mid s \models \ll \text{sees, Jon}, \dot{e}, LOC_1, TIM_1, 1 \gg]$$

the situation is typed from the outside.

Constraints may be natural laws, conventions, logical (i.e., analytic) rules, linguistic rules, empirical, law-like correspondences, etc.

For example:

smoke means fire.

If S is the type of situations where there is smoke present, and S' is the type of situations where there is a fire, then an agent (e.g., a person) can pick up the information that there is a fire by observing that there is smoke (a type S situation) and being aware of, or *attuned to*, the constraint that links the two types of situation.

This constraint is denoted by

$$S \Rightarrow S'.$$

(This is read as "S *involves* S'.")

Another example: FIRE *means fire*.

This describes the constraint

$$S'' \Rightarrow S'$$

that links situations (of type S'') where someone yells the word FIRE to situations (of type S') where there is a fire.

Awareness of the constraint

FIRE *means fire*

involves knowing the meaning of the word FIRE and being familiar with the rules that govern the use of language.

The three types just introduced may be defined as follows:

$$S = [\dot{s} \mid \dot{s} \models \ll \text{smokey}, \dot{t}, 1 \gg]$$

$$S' = [\dot{s} \mid \dot{s} \models \ll \text{firey}, \dot{t}, 1 \gg]$$

$$S'' = [\dot{u} \mid \dot{u} \models \ll \text{speaking}, \dot{a}, \dot{t}, 1 \gg \wedge \ll \text{utters}, \dot{a}, \textit{fire}, \dot{t}, 1 \gg]$$

Notice that constraints link types, not situations.

On the other hand, any particular instance where a constraint is utilized to make an inference or modify behavior will involve specific situations (of the relevant types).

Thus constraints function by relating various regularities across actual situations.

Infon logic.

We may form the *conjunction*, $\sigma \wedge \tau$, of two infons, σ, τ. The conjunction is not itself an infon, but a *compound infon*.

For any situation, s, we have

$$s \models \sigma \wedge \tau \text{ iff } s \models \sigma \text{ and } s \models \tau.$$

The *disjunction* of two infons, σ, τ, is a compound infon $\sigma \vee \tau$ such that for any situation s,

$$s \models \sigma \vee \tau \text{ iff } s \models \sigma \text{ or } s \models \tau \text{ (or both)}.$$

We regard the above definitions as clauses in a recursive definition of compound infons.

If σ is an infon (or compound infon) that involves the parameter $\dot{x}$ and u is some set, then

$$(\exists \dot{x} \in u)\sigma$$

is a compound infon.

For any situation, s, that contains (as constituents) all members of u: $s \models (\exists \dot{x} \in u)\sigma$ iff there is an anchor, f, of $\dot{x}$ to an element of u, such that $s \models \sigma[f]$.

The anchor, f, here may involve some *resource situation* other than s. f must assign to $\dot{x}$ an appropriate object in some anchoring situation, e, that supports the various infons that figure in the structure of $\dot{x}$.

Example. Let σ be the compound infon

$$\ll \text{tired}, \dot{c}, t_0, 1 \gg \wedge \ll \text{hungry}, \dot{c}, t_0, 1 \gg$$

where $\dot{c}$ is a parameter for a cat.

Let s be a room situation at time t_0 and u the set of individuals in s. Then:

$$s \models (\exists \dot{c} \in u)\sigma$$

iff there is an anchor, f, of $\dot{c}$ to some fixed object, c, in u (c necessarily a cat) such that $s \models \sigma[f]$, i.e., such that

$$s \models \ll \text{tired}, c, t_0, 1 \gg \wedge \ll \text{hungry}, c, t_0, 1 \gg .$$

That is to say, $s \models (\exists\dot{c} \in u)\sigma$ iff there is a cat, c, in u that at time t_0 is tired and hungry in s.

The existence of the anchor, f, entails the existence of an associated *anchoring* (or *resource*) *situation*, e, such that (in particular)

$$e \models \ll \text{cat}, c, 1 \gg .$$

In particular, c is a constituent of e.

Note that the object c has to be in the (room) situation, s, at time t_0 in order for the proposition

$$s \models \ll \text{tired}, c, t_0, 1 \gg \wedge \ll \text{hungry}, c, t_0, 1 \gg$$

to obtain.

If σ is an infon (or compound infon) that involves the parameter $\dot{x}$, and if u is some set, then

$$(\forall\dot{x} \in u)\sigma$$

is a compound infon.

For any situation, s, that contains (as constituents) all members of u:

$$s \models (\forall\dot{x} \in u)\sigma$$

iff, for all anchors, f, of $\dot{x}$ to an element of u, $s \models \sigma[f]$.

In the cases both of existential and universal quantification, the bounding set u may consist of all the objects of a certain kind that are in the situation s. Consequently, the definitions do provide a notion of 'unrestricted' quantification, but it is a notion of *situated* quantification.

For example, when I truthfully assert

All citizens have equal rights

I am presumably quantifying over some country such as the United States, not the entire world, for which such a claim is not true.

Naïve situation semantics.

We analyze utterances in terms of three situations:

- Utterance situation
- Resource situation
- Focal situation

The *utterance situation*. This is the context in which the utterance is made and received.

If Jan says to Naomi

A man is at the door

the utterance situation, u, is the immediate context in which Jan utters these words and Naomi hears them.

The situation u includes both Jan and Naomi (for the duration of the utterance), and should be sufficiently rich to identify various salient factors about this utterance, such as the door that Jan is referring to.

This is probably the one in her immediate environment, but not necessarily. For instance, if Jan utters the sentence *A man is at the door* as part of a larger discourse, the situation u could provide an alternative door.

The connections between the utterance and the various objects referred to, are known as just that: *connections* (or *speaker's connections*).

Thus

$$u \models \ll \text{utters}, \text{Jan}, \textit{A man is at the door}, l, t, 1 \gg \wedge$$
$$\ll \text{refers-to}, \text{Jan}, \textit{the door}, D, l, t, 1 \gg$$

where D is a door that is fixed by u.

The speaker's connections link the utterance (as part of u) of the phrase *the door* to the object D.

Resource situations. If Jan says

The man I saw running yesterday is at the door,

she is making use of a situation that she witnessed the day before, the one in which a certain man was running, in order to identify the man at the door.

There is another situation, r, a situation that occurred the day before the utterance, and which Jan witnessed, such that

$$\begin{aligned} u \models\ & \ll \text{utters}, \text{Jan}, \Phi, l, t, 1 \gg \wedge \\ & \ll \text{refers-to}, \text{Jan}, \textit{the man}, M, l, t, 1 \gg \wedge \\ & \ll \text{refers-to}, \text{Jan}, \textit{the door}, D, l, t, 1 \gg \end{aligned}$$

where Φ is the sentence

The man I saw running yesterday is at the door

and where Jan is making use of r and the fact that M is the unique man such that (for some appropriate values of l', t')

$$r \models \ll \text{runs}, M, l', t', 1 \gg .$$

Resource situations can become available for exploitation in various ways, such as:

1. by being perceived by the speaker;
2. by being the objects of some common knowledge about the world;
3. by being the way the world is;
4. by being built up by previous discourse.

The *focal situation*. That part of the world the utterance is about.

Features of the utterance situation serve to identify the focal situation. For instance, suppose Jan makes her utterance while peering out of the upstairs window at the house across the street. Then her utterance refers to the situation, s, that she sees, the situation at the house across the street, and we have

$$s \models \ll \text{present}, M, l, t, 1 \gg$$

where l is the location of the door and t is the time of the utterance.

Propositional content.

By adopting an ontology that includes items of information (infons), we are able to capture the notion of *the information* encoded by a representation, and can account for the fact that the same information can be encoded by two quite different representations, using quite different representation schemas.

There are then three notions that are often treated as if they were somewhat interchangeable, but which situation theory regards as quite distinct (though related):

- information
- representations
- propositions

In the case of a linguistic utterance, say Jon's utterance of the assertive sentence

Mary is running

the representation is the utterance itself, which we regard as a situation, call it u.

The *propositional content* of the utterance u is the proposition

$$e \models \sigma$$

where e is the focal situation, σ is the infon $\ll$ runs, $M, t_u, 1 \gg$, M denotes the individual Mary to whom Jon refers, t_u is the time of the utterance, and e is determined by various features of the utterance.

For example, e could be determined by Jon and the listener being part of some larger situation in which this individual Mary is running, or more generally by means of some other form of previously established context of utterance.

The propositional content is what might normally be referred to as the "information conveyed by the utterance".

§5. Papers on situation semantics.

The Situation Underground, with John Perry. ***Stanford Working Papers in Semantics***, vol. 1, edited by J. Barwise and I. Sag, Stanford Cognitive Science Group 1980, Section D, 1980, pp. 1–55.

This typed manuscript, dated 8/8/80, is, according to the authors' own introduction, little more than an assemblage of notes, written up in preparation for a talk Barwise was due to give at a workshop in Norway. A more polished account of a substantial part of the paper appeared in their subsequent article "Semantic Innocence and Uncompromising Situations", published in the ***Midwest Studies in Philosophy*** the following year.

For all its informal nature, the paper contains, at least in embryonic form, many of the key ideas of situation semantics, including situations, situation types, propositions, compositionality, negation versus denial, interpretation of definite descriptions, semantics of perception and attitudinal reports, semantics of complex noun phrases. Accordingly, as this is the first paper we consider, we devote much more space to this article than to any others.

The authors begin with a discussion of an argument they name *the slingshot*. Originally due to Church, the slingshot (so named by Barwise and Perry because it sets out to inflict maximum harm—on a situational semantics—with the minimum of raw materials) appears to render impossible a coherent semantic theory of natural language based on *situations*—structured parts of the real world.

In Church's original formulation, the slingshot considers the following four sentences:

1. Sir Walter Scott is the author of ***Waverly***.
2. Sir Walter Scott is the man who wrote the twenty-nine ***Waverly*** novels altogether.
3. The number, such that Sir Walter Scott is the man that wrote that many ***Waverly*** novels altogether, is twenty-nine.
4. The number of counties in Utah is twenty-nine.

By comparing each sentence with the one that follows it, and applying substitutions of equivalents, Church argued that all four sentences denote the same thing. Hence, since the first and the last sentence clearly have nothing in common except their truth value, he concluded that "all true sentences have the same denotation."

Barwise and Perry point out that Church's argument is fallacious, because it depends upon an unacknowledged, but crucial, shift of perspective. To go from sentence 1 to sentence 2, you replace one (valid) description of Scott by another. Similarly, you get from 3 to 4 by replacing one (valid) description of the number 29 by another. But this is not how you get from 2 to 3. Church recognized that there was a difference but felt it was insignificant. For Barwise and Perry, in contrast, it is the critical point where Church's argument breaks down. Adopting a situational approach, where statements refer to situations, they demolish the slingshot argument like this.[1]

Suppose first that the descriptions of Scott in sentences 1 and 2 serve simply to identify the individual Scott and likewise that the two descriptions of the number 29 in sentences 3 and 4 serve simply to identify the number 29. Then, sentences 1 and 2 refer to a situation whose only constituent is Scott and sentences 3 and 4 refer to a situation whose only constituent is the number 29. Clearly, from this perspective, you cannot get from 2 to 3.

In order to have any chance of being able to conclude that 2 and 3 designate the same situation, you have to take account of the properties involved in

[1]In trying to summarize their lengthy discussion into a few short paragraphs, I will inevitably lose some of the rigor and force of their argument. If you find my summary less than convincing, you should consult the original source. The same comment will apply to pretty well everything in this survey article.

the two definite descriptions. (For instance, the phrase "the author of ***Waverly***" is not interpreted simply as Scott, but, in Barwise and Perry's own words, "contributes the complex of objects and properties it mentions to the situations the sentence describes.") But then the denotations of 3 and 4 in particular are no longer the same.

In the paper, Barwise and Perry examine the slingshot in far greater detail, extending their discussion to Quine's version of the argument and the role played by logical equivalence. For example, they point out that the following two sentences do not designate the same situation, even though the embedded sentences are logically equivalent:

1. Fred sees Betty enter.
2. Fred sees Betty enter and (Sally smoke or Sally not smoke).

In 1, the situation Fred sees has Betty as the sole individual constituent, in 2 Fred sees a different situation, one that has both Betty and Sally as constituent individuals.

Having disposed of the slingshot, Barwise and Perry sketch the elements of a semantic theory based on situations. In so doing, they build upon the insights gained in their analysis of the slingshot. Their account includes some early fragments of the mathematical modeling that would later develop into mathematical situation semantics (as described in their 1983 book ***Situations and Attitudes*** and several subsequent papers by Barwise and others, and eventually summarized in my own book ***Logic and Information*** in 1991). But at this stage the mathematics may with hindsight be viewed as merely a pointer to things to come. The force of the paper is in introducing some of the key ideas of situation semantics and identifying some of the main themes that would guide its development.

Barwise and Parry declare their development to be guided by the two methodological principles:

- at the level of interpretation, statements designate types of situations;
- "modest compositionality": the interpretation of a sentence is a function of the interpretation of its parts.

They say:

> "A sentence is a sentence of some language and part of what the language provides is the linguistic meaning of the sentence. In a particular use, the linguistic meaning provides interpretations of the parts and the whole. The interpretation of the whole is to be the set of situation types designated by the statement."

Picking up from their resolution of the slingshot, they explicitly distinguish (as a feature of their theory) between what they call *value-free* and *value-loaded* interpretations of definite descriptions. The value-free interpretation of "the author of ***Waverly***" contributes the property of being the author of ***Waverly***; the value-loaded interpretation contributes Scott. This distinction pervades all of their subsequent work in situation semantics. The mathematical model they start to develop in this paper and flesh out to a much greater extent in later work has machinery to cope with this distinction. Again adding a formal gloss that was really only brought out explicitly in later work, a definite description such as *The* ϕ determines a function from the situation in which it is uttered to a property or an individual. Already in the current paper this machinery is sufficiently well developed to demonstrate that a statement such as *The* ϕ *is* ψ has four possible interpretations as different propositions.

They end their paper with a brief comparison of their situation semantics with possible world semantics, arguing that both common sense and analogy with mathematics make the situational approach far more preferable than possible worlds—another theme they would take up again in later work.

Semantic Innocence and Uncompromising Situations, with John Perry, ***Midwest Studies in Philosophy VI***, 1981, pp. 387–403. (Also published in ***The Philosophy of Language***, edited by A. P. Martinich, Oxford University Press, 1985, Chapter 30.)

To a large extent, this is a more polished version of a substantial part of *The Situation Underground*. The clever pun in the title (for the benefit of non-native speakers of English let me mention that a "compromising situation" is generally one where someone is found engaged in illicit sexual activity) gained an additional twist when the paper was subsequently reprinted in the compilation volume edited by Martinich, where the final word of the title was left off, leaving the title page reading "Semantic Innocence and Uncompromising Jon Barwise and John Perry." An ironic phrase, given the degree of compromise involved in the subsequent development of situation semantics.

They begin by introducing situations and situation types. In so doing, they discuss properties and relations, pointing out that they view them as real (abstract) objects in the everyday world, not set-theoretic constructs. They then lay out the basic philosophy of situation semantics. They claim that sentences have meanings and when uttered give rise to interpretations and evaluations. The interpretation arises by virtue of circumstances of the utterance. Examples of evaluation are (i) determining whether a given type of situation is in a given proposition, (ii) determining the extension of a property in a given situation, and (iii) determining the properties an individual has in a given situation. they state two principles that guide their development:

1. At the level of interpretation, indicative statements designate types of situations;
2. The meaning of a statement is a function of the meanings of its parts.

They distinguish between value-free (attributive) and value-laden (referential) uses of definite descriptions and discuss the difference between the two.

They provide an informal but rigorous development of the situation semantics of various attitude reports involving "sees"' and "believes that".

They discuss and resolve the slingshot and previously perceived problems about logical equivalence, along the way considering contributions by Frege, Church, Quine, and Davidson.

Situations and Attitudes, with John Perry, ***Journal of Philosophy***, vol. 78, no. 11, 1981, pp. 668–691.

The authors use the framework of situation semantics to investigate the semantic structure of statements of the forms

- John says ...
- John sees ...
- John sees that ...
- John knows that ...
- John believes that ...

Their goal is to ground (as far as is possible) the interpretations of such statements in actual situations in the world and in various relevant properties of the world. This approach works well for "says" statements (where the statement is taken to refer to a particular utterance John made), for "sees" and "sees that" statements (where there is an actual situation that John sees, and the distinction between the two kinds of report lies in the familiar *de re–de dicto* distinction) and for "knows that" reports (similar to, though not identical to, the "sees that" reports). But it does not work so easily for "believes that" reports, which seem unavoidably to involve reference to some form of cognitive state that John possesses.

Many commentators have concluded that this approach to the semantics of "says", "sees", "sees that", and "knows" reports not only resolves, in a straightforward and elegant fashion, many of the traditional puzzles about such reports that plagued previous generations of analysts, it also provides an excellent illustration of the way the basic concepts of situation semantics may be used to analyze language use.

The authors use the same title for their 1983 book on situation semantics, but while the subject of the 1981 paper is a part of that later work, the book addresses many issues not mentioned in the paper.

Scenes and Other Situations, ***Journal of Philosophy***, vol. 78, no. 7, 1981, pp. 369–397. (Reprinted in ***The Philosophers Annual V***, edited by D. Boyer, P. Grim & J. Sanders, Rowman & Littlefield, 1982, pp. 67–96; also reprinted in Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes, 1988, Chapter 1.)

The Barwise and Perry collaboration that led to situation semantics arose in part from Barwise's attempts to develop a theory of perception reports, based loosely on the model-theoretic semantics of mathematics, and Perry's work on belief reports. In this paper, Barwise spells out much of his early work on perception reports, in particular reports where the embedded clause is a so-called “naked infinitive”, as in

John saw Mary run

or the gerundive form

John saw Mary running.

His intention in providing a sound theory of perception reports of this nature is to carry out the first step of a divide-and-conquer approach to perception reports in general. He believed—and this paper demonstrates the fact—that an adequate semantics for such reports can be given without the need for epistemic considerations regarding the reporter, thereby opening the way for a subsequent analysis of epistemically loaded reports such as

John saw that Mary ran

to be developed by adding epistemic considerations into the mix.

The basic idea is simple enough. The interpretation of the statement *John saw Mary run* is that there was a scene (a situation) that John witnessed, in which the individual Mary ran. By staying true to this basic intuition, and developing his arguments carefully and precisely, Barwise is able to execute a fairly thorough analysis of the logic of such reports that avoids the puzzles that had plagued other treatments.

Although his analysis is heavily dependent on the fundamental ideas of situation semantics, in this paper Barwise avoids introduction of the mathematical formalisms of that theory, and instead presents his arguments largely in prose, with an occasional use of more traditional logical formalisms.

Some Computational Aspects of Situation Semantics, ***Proceedings of the 19th Annual Meeting of the ACL***, Association for Computational Linguistics, 1981.

Barwise compares situation semantics and possible words semantics from a computational point of view. Starting from the observation that major advances in recursion theory followed the step from restriction to total functions to the inclusion of partial functions, the paper makes a similar claim for natural language semantics. Situations can be viewed as partial possible worlds, and situations have computational tractability whereas possible worlds do not.

Information and Semantics, ***Behavioral and Brain Sciences***, vol. 6, 1983, p. 65.

This single-page article is a review of Dretske’s book ***Knowledge and the Flow of Information***, a work that Barwise and Perry acknowledge elsewhere in their writings exerted a major influence on their development of situation semantics. The review is as much a critique of approaches to a theory of information based on traditional model theory as it is a commentary on the probabilistic-based definition of information that forms the core of Dretske's book. *Vis á vis* Dretske, Barwise argues that it is a mistake to view information as independent of the language used to convey it, as Dretske does, and gives simple examples to illustrate why information flow depends crucially on knowledge of the linguistic (or other) relations (*sic*—what he and Perry elsewhere call constraints) that govern its transmission in simple everyday cases. For all its brevity, this article summarizes much of the philosophy that underlies the development of situation semantics.

Shifting Situations and Shaken Attitudes, An Interview with Barwise and Perry, ***Linguistics and Philosophy***, vol. 8, no. 1, 1985, pp. 105–161. (Also CSLI Report No. CSLI-84-13, 1984.)

This lengthy paper is written in the form of a magazine interview with Barwise and Perry. (There was no interviewer, but it was a cute idea, and a good way for B&P to address many issues raised by commentators on their work.) They use the paper to reflect (often at length) on the changes in their views that have occurred during the development to date of situation semantics, and respond to critiques by a number of linguists and philosophers, both of their work in general and their 1983 book ***Situations and Attitudes*** in particular. They also devote a considerable portion of the discussion to the problems they saw with Montague Grammar and possible world semantics (viewed by many as the main competitor to situation semantics) and why they believed situation semantics was a better vehicle for understanding how language serves as a vehicle for the transmission of information. To a large extent the article can be viewed as a reflective addendum to their 1983 book.

The article was published in a special issue of ***Linguistics and Philosophy***, along with a number of critiques of situation semantics, the most notable among them being Soames' article "Lost Innocence," which led them to make the revisions to their theory that they outlined in the "Shifting Situations" paper.

The paper will be fairly inaccessible to a reader not familiar with their earlier work on the subject, and in places they also assume familiarity with commentaries written by their critics. But for anyone with the requisite background, the paper is rich with insights as to why they developed the theory the way they did and how and why their views changed. The magazine interview format also serves to make relatively easy reading of some fairly deep issues in the philosophy of language that played large in their development of situation semantics, ranging over realism, efficiency of language, partial information, and their account of attitude reports.

*Review of "**Inquiry**" by Robert C. Stalnaker*, ***The Philosophical Review***, vol. 95, no. 3, 1986, pp. 429–34.

This short article is a book review. I include it in this compilation because, while it does not provide any direct account of Barwise's own ideas, it sheds light on some of his own thinking that led him to his development of situation semantics, with John Perry.

In ***Inquiry***, Stalnaker sets out to motivate and develop possible worlds semantics. Problems that arise from the total nature of possible worlds led Barwise and Perry to base their analysis of language on *partial* worlds, what they called situations. In the course of his review of Stalnaker, Barwise looks in detail at some specific problems associated with possible worlds, problems which Barwise and Perry believed are avoided with a situation-based approach.

Recent Developments in Situation Semantics, ***Language and Artificial Intelligence***, edited by M. Nagao, Elsevier, 1987, pp. 387–399.

In this brief article, presented at a conference in Japan, Barwise surveys the current state of play in research in situation semantics. He begins by pointing out that a semantic theory based on the notion of the information conveyed by a linguistic utterance, is inevitably a special case of a more general theory of information and representations thereof. He reports that regular exchanges between the situation semanticists at Stanford and researchers in linguistics, computer science, AI, logic, and philosophy from Stanford and the nearby SRI and Xerox PARC, facilitated by the establishment of the STASS research group (Situation Theory and Situation Semantics), have led to the beginnings of the development of a new theory—situation theory—that is intended to provide the basis for situation semantics in particular and more generally for studies of information flow and computation. He argues for an increasing emphasis on such highly cross-disciplinary research, acknowledging that it was the feedback from others disciplines that led him and Perry to abandon the set-theoretic modeling that was characteristic of much of their early work on situation semantics.

By way of providing a general sense of what the STASS group had already achieved, Barwise finishes the article by giving a glossary of the various formally defined terms of situation theory. The fact that he lists 48 individual terms, each of which has been given its own specific, formal definition, illustrates the complexity of the task being undertaken.

Model-Theoretic Semantics, with John Etchemendy, ***Foundations of Cognitive Science***, edited by M. Posner, MIT Press, 1989, pp. 207–243.

This article is a chapter of an expository book. It sets out to explain to readers familiar neither with semantics in general nor with model-theoretic semantics in particular, just what those enterprises are about.

Following a lengthy discussion based on an artificial language fragment for talking about planetary orbits, which the authors use to exemplify the basic ideas of semantics and of model-theoretic semantics, they describe, in brief outline, possible worlds semantics and situation semantics.

The article is almost entirely expository, written at an introductory level for a fairly general audience, and is unlikely to be of much interest to readers of this survey of Barwise's research on language, except to acknowledge that he took education seriously, and to illustrate his skill in that task.

Situations and Small Worlds, in Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989, Chapter 4. (Also published in German translation as "Situationen und kleine Welten", in ***Semantik***, edited by A. von Stechow & D. Wunderlich, de Gruyter, 1991, pp. 80–89.)

Barwise compares situation semantics with possible world semantics. In part, the paper is a response to criticisms of situation theory by M. J. Creswell. In presenting his arguments, Barwise provides a brief summary of the main philosophical assumptions underlying situation semantics.

Barwise raises again here some of the issues he covered in his earlier papers *Some Computational Aspects of Situation Semantics* and *Review of "**Inquiry**" by Robert C. Stalnaker*. Looking back, with my own mathematician's perspective, on the ongoing debate Barwise and Perry had with a number of leading figures in the possible worlds semantics camp, it seems that much of the debate was a result of the p.w. advocates not taking enough notice of the mathematical examples Barwise kept referring to. Consideration of the huge positive significance to recursion theory that resulted from the realization that a theory of computation should be developed for partial functions, not total ones, was one of the main motivators for Barwise to work on situation semantics. He felt that semantics should take seriously the lessons from recursion theory. That's why he kept using the examples in his papers. Unfortunately, critics of situation semantics simply ignored the comparison with recursion theory, feeling presumably that it had no significance for semantics, a dangerous assumption if you think that there is any form of computation involved in the way the brain processes language. Barwise himself said (to Perry[2]) that it was purely an historical accident that partial functions were developed after model theory, and that accident of timing was the principal reason why partiality was largely ignored in both model theory and possible world semantics.

Situations, Facts, and True Propositions, in Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989, Chapter 10.

In this paper, Barwise presents an in-depth analysis of three concepts—the three listed in the title—that situation theory takes as distinct but which some other distinguished scholars have taken to be the same in various combinations. Among the claims he puts forward are:

- Situations can arise out of the interaction of cognitive agents and their environment. They are metaphysically prior to facts, which arise out of the classification of situations.

[2]Reported to me by Perry as I was working on this survey.

- Focus situations (of a cognitive act by a situated, cognitive agent) can be determined by the cognitive activity of the agent, and hence are relative to the agent's perspective.
- Facts are relative to the focus situation s of concern to a situated, cognitive agent.
- Facts are metaphysically on a par with objects, properties, and relations, but prior to propositions.
- A basic proposition p classifies the agent's classification of the focus situation. It is of the form [s is of the form σ]. It will be a true proposition just in case σ correctly classifies s.

Barwise shows how the perspectival nature of the focus situation provides a resolution to Kripke's well known puzzle about the Frenchman Pierre who believes Londres is pretty but, on visiting London for the first time (and not realizing that Londres is London) thinks that it is an ugly city.

Notes on Branch Points in Situation Theory, in Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989, Chapter 11.

This is a fairly technical paper that lists (with brief discussions) some of the main choices that were facing the small community of situation theory developers in the late 1980s. Although the focus is situation theory, some of the issues arose from, and had consequences for, situation semantics, and accordingly we decided to include the paper in this survey. Anyone interested in further developing situation theory and/or situation semantics would likely find the paper very helpful, but most readers of this survey are likely to find it of limited benefit.

§6. Papers on mathematical linguistics.

Generalized Quantifiers and Natural Languages, with Robin Cooper, ***Linguistics and Philosophy***, vol. 4, no. 2. pp. 159–219. (Also published in ***Stanford Working Papers in Semantics***, vol. 1, edited by J. Barwise and I. Sag, Stanford Cognitive Science Group 1980, Section 68 V. I, pp. 325–385.)

In this paper, the authors develop a uniform mathematical framework for expressing and analyzing various quantifiers that arise in ordinary discourse, such as

- There are only a finite number of ...
- No ...
- More than half of ...
- Most ...

None of these quantifiers, the observe, can be expressed in terms of the standard logician's quantifiers "for all" and "there exists".

Their methodology is to base their framework and analysis on linguistic observations and intuitions, rather than any sense of logical necessity. The framework they develop is, by their own admission, not psychologically plausible, but nevertheless, they claim, sheds light on the actual use of quantification in real life language usage. A considerable part of their paper is devoted to using their framework to deduce plausible linguistic universals for natural language use.

They begin by claiming that natural language quantifiers correspond to noun phrases, not determiners. For example, in the phrase "most people", the word "most" should be viewed as a determiner; the quantifier is the entire phrase "most people".

They take quantifiers to denote the family of sets for which they yield the value "true". The denotation of a quantifier Q is denoted by $\|Q\|$. For example, if E is the domain in question,

- $\|\exists\| = \{X \subseteq E \mid X \neq \emptyset\}$,
- $\|\forall\| = \{E\}$,
- $\|\text{Finitely many}\| = \{X \subseteq E \mid X \text{ is finite}\}$,
- $\|\text{More than half of } N\| = \{X \subseteq E \mid X \text{ contains more than half of the } N\text{'s}\}$,
- $\|\text{Most } N\| = \{X \subseteq E \mid X \text{ contains most } N\text{'s}\}$.

Given an expression $\phi(x)$ that involves some variable x, they denote by $\hat{x}[\phi(x)]$ the set of all those x for which $\phi(x)$. For any quantifier Q, the truth of the sentence $Qx[\phi(x)]$ is determined by whether or not the set $\hat{x}[\phi(x)]$ is a member of the denotation of Q.

The bulk of the paper comprises a fairly detailed and mathematically technical analysis of this formally defined notion, together with the deduction of conclusions for actual language use.

Noun Phrases, Generalized Quantifiers and Anaphora, ***Generalized Quantifiers: Linguistic and Logical Approaches***, edited by E. Engdahl and P. Gärdenfors, Reidel Studies in Language and Philosophy, 1986.

This paper builds on Barwise's paper *Generalized Quantifiers and Natural Languages*. with Robin Cooper, and on Barwise and Perry's work on situation semantics. Motivating his development with a series of carefully chosen examples of natural language quantification and anaphora, Barwise defines a formal language that corresponds to a fragment of natural language, and develops a model theory for that language which models noun phrases, various kinds of quantifiers, and anaphoric dependencies. A key component of his development, of particular relevance to capturing anaphora, is an action-oriented notion of satisfaction:

$$f \;\Rightarrow\; \chi \models \phi \;\Rightarrow\; f'$$

where f and f' are partial variable assignments, ϕ is an expression of his formal language, and χ is an object of some type depending on the syntactic category of ϕ. The intuition is that if f represents the interpretation of pronouns prior to the introduction of ϕ then f' is an extension of f that is available after producing ϕ.

§7. Papers on logic, thought and information.

The Situation in Logic–I: Logic, Meaning and Information, CSLI Report No. CSLI-84-2. (Also published in ***Proceedings of the VII International Congress for Logic, History, and Philosophy of Science, Salzburg, 1983***, North Holland, 1984, and in ***Logic, Methodology and Philosophy of Science VII***, edited by B. Marcus et al., Elsevier, 1986, pp. 183–203, and as "Logic and Information", Chapter 2 of Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications 1989.)

This paper, the first of a series of four, was presented at the 1983 International Congress in Logic and Philosophy of Science, held in Salzburg.

Although connected with his work on situation semantics with Perry, in all four papers in this series Barwise addresses what he sees as a more general issue, of which natural language semantics is just one special case, albeit an important one that greatly influenced his thinking.

He argues against the traditional identification of "logic with first order logic, or indeed any logic based upon truth-values," and suggests instead that logic should be viewed as the study of inferences, based on an acquisition of information. Language and linguistic meaning are but special cases of more general phenomena of information flow, inference, and meaning. For Barwise, the main focus in semantics should be, in the case of declarative sentences: (1) under what conditions a sentence can be used to convey information, and (2) what information the sentence conveys under those questions.

The key distinction that supports his development is between "type-meaning" and "situation meaning". He illustrates the distinction by contrasting an utterance of the sentence "Cat hair in the butter always means that a cat has been on the table," which expresses the type-meaning of cat hair in the butter, from an utterance, in a particular circumstance, of the sentence "That cat hair in the butter means that the cat has been on the table," which refers to a situation meaning.

People and other cognitive agents make inferences by recognizing the particular situations are of certain types and making use of regularities between types, Barwise argues. Thus, it is at the level of types that we should look for logic—for the rules that describe how agents make inferences. He writes:

> " . . . meaning, be it natural or conventional, linguistic or cultural, resides in systematic relations of a special sort between different types of situations—relations to which agents are attuned. Systematic constraints between types of situations are what allows one situation to contain information about another situation. An agent's attunement to such constraints is what allows the agent to infer soundly from the one's being the case to the other's being

> the case. Said in different words, type-meaning is what allows an event of a particular type to have situation-meaning. Attunement to type-meaning is what allows an agent with information about the first to soundly infer what it situation-means."

The Situation in Logic–II: Conditionals and Conditional Information, CSLI Report No. CSLI-85-26. (Also published in ***On Conditionals***, edited by E. C. Traugott, C. A. Ferguson, & J. S. Reilly, Cambridge University Press, 1986, and as Chapter 5 of Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989.)

In this substantial paper, Barwise presents a number of examples from both everyday language use—including some well known puzzles from the philosophy of language literature—and within mathematics that demonstrate major problems with both the material conditional and the ways conditionals are handled in possible worlds semantics. He then presents his own treatment of conditionals, based on the ideas of situation semantics, and shows how this approach handles the examples that caused the other theories to falter.

The basic idea is to take the interpretation of a conditional to be a constraint (in the formal sense of situation theory). The possible occurrence of parameters in both the antecedent and the consequent of a constraint allows both for the distinction between general conditionals (often expressed using the subjunctive and present indicative tenses—e.g., "*If it is raining, the event is postponed.*") and specific conditionals (generally expressed using the present indicative and future tenses—e.g., "*If it rains, the event will be postponed.*"), and for capturing the all-important causal connection between antecedent and consequent that more traditional mathematically-based semantic theories do not.

From a situation-theoretic viewpoint, one important feature of this paper is that it presents a motivated and fairly detailed account of the role of (generally unarticulated) background conditions in the way constraints function. This is one of the key indicators of the shift in thinking in situation theory and situation semantic circles that took place in the mid 1980s, leading away from the view that situation theory should be an extensional, set-theoretic theory toward the realization that it inevitably had essential intensional aspects.

The Situation in Logic–III: Situations, Sets and the Axiom of Foundation, CSLI Report No. CSLI-85-26, 1985. (Also published in ***Proceedings of the 1984 Logic Summer School***, edited by A. Wilkie et al., North Holland, 1986, and as Chapter 8 of J. Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989.)

This is a mathematical paper, in which Barwise begins to examine the mathematical properties of situation theory—more precisely, the mathematical properties an intended, future, formal mathematical development of situation theory will have to have in order to meet the needs of situation semantics. In particular, he considers the kinds of set theory that would be associated with such a theory, concluding that it would have to allow for non-well-founded sets.

This paper marks another step in the gradual shift in situation-theoretic circles from a synthetic approach to an analytic one. In their 1983 book ***Situations and Attitudes***, Barwise and Perry tried to build up situations in a traditional set-theoretic fashion, acknowledging a tacit assumption of Kripke-Platek (admissible) set theory with urelements (KPU). This approach led to a number of technical difficulties, and ultimately caused them to conclude that it was a mistake. Instead, they decided, situations should be taken as basic—structured parts of reality—and part of the task of situation theory would be to analyze those basic entities.

Part of such an analysis would be to examine what kind of sets would be left when all the structure of a situation was stripped away. Various considerations Barwise presents in this paper lead to the conclusion that such a set theory would admit non-well-founded sets.

The paper ends with a brief introduction to a particular non-well-founded set theory developed at about the same time by Peter Aczel. In a subsequent book with John Etchemendy (***The Liar***, published 1987), Barwise uses Aczel's set theory together with a more fully worked out version of some of the ideas in this paper to provide a mathematical resolution of the Liar Paradox.

Information and Circumstance, ***Notre Dame Journal of Formal Logic***, vol. 27, no. 3, 1986, pp. 324–338.

This paper is in part a response to Jerry Fodor's critique of situation semantics given in his paper "Information and Association," presented at the APA meeting in San Francisco, March 23, 1985. Fodor argued from his familiar Language of Thought assumption (that thought consists of mental manipulations of formal, symbolic representations, similar to formal deduction in proof theory).

Barwise claims that the information provided by a representation, while it may be an objective feature of the representation, is definitely not intrinsic to it, but is essentially relational, depending on constraints—constraints that make the information dependent on the surrounding (or embedding) circumstances. He discusses at some length the mechanism by which the representation and the embedding circumstances may combine to yield the information, giving both linguistic and non-linguistic examples. He considers four different ways that the embedding circumstances can contribute to the information carried by a signal: articulated constituents and context, unarticulated constituents, articulated nonconstituents, and unarticulated nonconstituents. He illustrates these for the case of natural language.

The articulated constituents are determined by the context, and include the interpretations of "I", "him", "here", "now", "today", "Jon", etc.

The unarticulated constituents include items such as the location for an utterance such as "It is raining." For such an utterance, there is no articulated constituent that says where the raining is taking place, as there is with an utterance of "It is raining here."

Among the articulated nonconstituents would be the location where the person being referred to is named Jon in an utterance of "Jon is coming too" or the location that determines that the person referred to by "she" is female.

The unarticulated nonconstituents for an utterance include the background assumptions that the utterance depends on; for example, the fact that the location referred to is on or near the Earth's surface when a person says "If you hold an egg up and release it, it will fall toward the ground."

Barwise then moves on to an account of inference, which in contrast to Fodor he claims is not formal but situated, exploiting various features of the surrounding circumstances. He provides four possible mechanisms for making a situated inference: exploiting environmental constraints, use of circumstantial rules of inference, making implicit parameters explicit, and moving from self-relativity to self-reference.

An example of exploiting environmental constraints occurs when we conclude that an egg held up and then released will fall to the ground. We do not need to know anything about gravity to make this inference; it is enough that we are on or near the surface of the Earth when we make it.

A computer on an airplane that receives its time signals from its home base and automatically adjusts to the time zone it is flying in depending on how far it has flown in what direction, but which has no information about time zones, would be making use of circumstantial rules of inference, since its getting the right answer depends crucially on where it is at the time.

We make an implicit parameter explicit when we go from "It is raining" to "It is raining here" or "It is raining in Los Angeles."

Going from "Jon is to the left of Alice" to "Jon is to the left of Alice from my viewpoint" is an example of moving from self-relativity to self-reference.

Overall, this paper provides an excellent introduction to Barwise's thinking at the time on the nature of information and inference, and the different ways contextual features can play a role.

On the Circumstantial Relations between Meaning and Content, ***Versus***, vol. 44, pp. 23–39. (Also published in ***Meaning and Mental Representations***, edited by U. Eco, M. Santambrogio & P. Violi, Indiana University Press, pp. 23–40, and as Chapter 3 of Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications 1989.)

This paper has considerable overlap with *Information and Circumstance*, but here Barwise's main focus is on meaning, with a particular view toward the interpretation of literary fiction. After recapping much of the material in I&C he introduces the equation

$$C_R(S, c) = P$$

that connects a symbol S, circumstances c, and conventional constraints R to the content P. (C stands for "content".) By thinking in terms of this relationship, he says, many of the traditional puzzles about language disappear.

In particular, he says, "one is no longer tempted to think that all the possible information one can extract from a statement is somehow part of its content. Information about each of the parameters in the equation gives information about all the others."

Taking the equation as his starting point, he analyzes the nature of linguistic communication and interpretation in general, and literary authorship and interpretation in particular. He does not set out to discover any great truths that will surprise literary scholars, but his analysis does shed an interesting new (and perhaps clarifying) light on a domain that had hitherto been largely off limits to mathematical logicians.

Unburdening the Language of Thought, ***Mind and Language 2***, 1987, pp. 82–96.

This paper is in some ways a continuation of Barwise's earlier paper *Information and Circumstance*, and as such is part of an ongoing public debate Barwise had with Jerry Fodor. But whereas I&C focused on information and communication, this paper is about the nature of computation and inference. Barwise claims that computation and inference are situated activities, that can depend in essential ways on the embedding circumstances. Much of the discussion is in terms of a single, simple example (an imaginary robot called Domino that delivers pizza) to demonstrate this context dependency. Domino is designed in such a way that certain of its programmed actions depend in a regular way upon features in the environment that are not explicitly programmed in.

This paper is best read in conjunction with the one that follows it in the journal, *Cognition, Attunement and Modularity*, by Terry Winograd (op. cit. pp. 97–103), where the author introduces a slightly different robotic example to pursue Barwise's ideas further and head off some objections that could be levied against the Barwise example. Taken together, these two papers provide a good introduction to the key ideas of situated computing.

The Situation in Logic–IV: On the Model Theory of Common Knowledge, CSLI Report No. CSLI-88-122. (Also published as Chapter 9 of Jon Barwise, ***The Situation in Logic***, CSLI Lecture Notes 17, CSLI Publications, 1989.)

Barwise uses ideas from situation theory to provide a new (third) analysis of common knowledge.

Common knowledge is when two people know the same thing in a joint fashion, where each is fully aware that they *both* know it. The traditional analysis is in terms of an infinite regress. Agents A and B have joint knowledge of some fact σ if all of the following:

- [A knows σ] and [B knows σ]
- [B knows that A knows σ] and [A knows that B knows σ]
- [A knows that B knows that A knows σ] and [B knows that A knows that B knows σ]
- ...
- ...

Another analysis is the so-called fixed-point account. If τ denotes the fact that the knowledge of σ is common to the two agents, then τ has the following analysis:

$$A \text{ and } B \text{ know } (\sigma \text{ and } \tau)$$

The third approach, which Barwise acknowledges originated with Clark and Marshall, is the one he develops using situation-theoretic machinery. A and B have common knowledge of σ if there is a situation s such that

- $s \models \sigma$
- $s \models A$ knows s
- $s \models B$ knows s

The paper examines the relative merits of these three analyses of this important phenomenon. A companion paper, "Three Views of Common Knowledge", provides a less mathematically technical but more philosophical treatment of the same topic.

Three Views of Common Knowledge, ***Theoretical Aspects of Reasoning about Knowledge, II***, edited by M. Vardi, Morgan Kauffman, 1988, pp. 365–379.

Barwise claims that in thinking about common knowledge, three questions must be kept separate: (i) What is the correct analysis of common knowledge? (ii) Where does it come from? (iii) How is it used? His analysis suggests that the fixed point approach gives the right theoretical analysis of the pre-theoretic notion of common knowledge, but the shared-environment approach is the right way to understand how common knowledge usually arises and is maintained over an extended interaction. He acknowledges, however, that the shared-environment approach does not offer an adequate characterization of the pre-theoretic notion, since a given piece of common knowledge may arise from different kinds of shared environments. (The fixed-point approach does fine in this respect.) He shows that in the case of having information, the iterate approach and the fixed-point approach are equivalent if you restrict to finite situations, but otherwise the iterate approach is too weak. And for knowledge, the iterate approach cannot be justified under any circumstances.

Information, Infons, and Inference, with John Etchemendy, ***Situation Theory and Its Applications***, vol. 1, edited by R. Cooper, K. Mukai & J. Perry, CSLI Publications, 1990, pp. 33–78.

In this paper, the authors present the beginnings of a general theory of heterogeneous (or multi-modal) reasoning. The theory they present was developed in parallel with their work on an educational computer program called *Hyperproof*, which allowed students to reason with information presented in both visual and linguistic forms. The paper adopts a mathematical presentation style, with formal definitions, beginning with a formal definition of information (infons) and an associated structure (infon algebras). After showing how infon algebras relate to the broader context of work in situation theory, the authors present an account of logical reasoning as cumulative information extraction, formulating a suite of five principles of inference that (they claim) are sufficient for all forms of reasoning. The paper concludes with a worked example and a brief comparison of their theory with other approaches. This is an excellent paper for the more mathematically oriented logician who wants to move beyond the classical, truth-based treatment of proof.

§8. Epilogue. A personal note to end with. I first met Jon Barwise in Oslo, in the fall of 1972. I was there for the semester, a year after finishing my Ph.D., and Jon came out to give a talk. I volunteered to drive out to the airport to meet him and bring him to the university. We hit it off immediately—in particular his mid-Western sense of humor gelled well with my British one. (As we walked along the corridor from the terminal building to the parking lot, flanked on both sides by advertisements, we saw a sign that said "Advertise here." "Use the Barwise Compactness Theorem!" Jon quipped.) Sadly, we came into contact only rarely in the ensuing years, generally at the occasional conference, and once, in 1976, when I went out to the University of Wisconsin to give a talk and I went with Jon and the other Wisconsin logicians for dinner at the Rudins' house (Walter and Mary Ellen). Jon was editing the North Holland ***Handbook of Logic*** and by chance almost all of his contributing authors were present at that dinner.

In the early 1980s, my interests in logic, and a side-interest in computing and artificial intelligence, carried me in the direction of trying to understand information. I made little progress, but then, in 1984, at a large ASL meeting in Manchester, I attended Jon's plenary talk, and was blown away by what he said. Although the vast majority of the audience were perplexed—indeed many were dismayed or dismissive—I recognized at once that his attempts to get to the heart of information flow, while still very embryonic, were profound. I went up to him afterwards and expressed my enthusiasm. He told me about the new interdisciplinary research center he had just helped create at Stanford, CSLI, of which he was the first director.

The next year I flew out to Stanford to attend the ASL conference that CSLI hosted. By then, I had read everything Jon and John (Perry) had written on the new subject of situation semantics that I could lay my hands on, including their controversial new book ***Situations and Attitudes***. Unfortunately, the enormous skepticism toward situation semantics on the part of the mainstream mathematical logic community was shared by the new Vice Chancellor of my home university, Lancaster University. My growing interest in situation semantics met with considerable opposition from a university administration that wanted me to turn myself into a "respectable, mainstream computer scientist" (which had positive, albeit short term, funding implications for them). Thus, when Jon, knowing of my increasingly gloomy plight at Lancaster, invited me to spend the year 1987–88 at CSLI as a Visiting Researcher, I was doubly motivated to accept. With Lancaster exerting increasing pressure on me not to return, I took advantage of an opportunity to spend a second year at CSLI, and in the end never returned to Britain. I tell this story because it says a lot about Jon. First, he was a truly honorable person. He was deeply outraged that a university administration should seek to pressure faculty to conform to some form of politically correct mold and avoid striking out into novel territory. (In my case, territory that Jon himself was pioneering! I think he saw it as a judgement of his work as much as mine.) But Jon was not just angry; he did something about it. The opportunity for me to spend two years at CSLI, which Jon provided, changed my career and my life. Disillusioned and dismayed by my Lancaster colleagues, I was on the point of leaving academia and mathematics altogether. Jon brought me back. I will remain forever in his debt for all the good turns both my career and life have taken since then. This is why I gladly accepted the invitation to write this summary. Jon was my inspiration, my teacher, my colleague, and my good friend. I miss him badly.

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