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## Book Reviews

KEITH DEVLIN. *Logic and Information*. Cambridge: Cambridge University Press, 1991. Pp. xii + 308. ISBN 0-521-41030-4 (cloth).

Review by NEIL TENNANT\*

This is a book, for the technically sophisticated non-specialist, about situation theory. Situation theory, as we shall see, helps itself (perhaps unwittingly) to ideas from a variety of philosophical traditions in an attempt to be mathematically comprehensive and precise about the flow of information in cognitive agents' perception, thought and communication about the world. The *seminal work* in situation theory was that of Barwise and Perry, best represented in their book *Situations and Attitudes*.<sup>1</sup> The *motivation* for situation theory comes from our urgent need for an adequate science of information, and for a mathematical theory that can provide the abstractions with which the interesting generalities of that science can be expressed. The *technical inspirations* behind situation theory come from set theory, type theory and model theory. The *problems* dealt with by situation theory come mainly from pragmatics, that previously neglected subfield of linguistics that is supposed to deal with aspects of language in use, with context of utterance, with demonstratives, indexicals and token-reflexives ('I', 'you', 'here', 'now', 'this', 'that',...). The *challenges* faced by situation theory come both from the inertia of orthodoxy in modern logic that inhibits fundamental overhaul of our conceptions of interpretation and of inference, and from the limitations and internal problems faced by precursor theories such as Montague grammar, in dealing with intensional verbs (e.g., 'cause', 'perceive' and 'believe') in natural language. Finally, the *successes* claimed by situation theory remain somewhat indeterminate. The leading theorists have roughed out a certain framework of concepts that are to a certain extent mutually supporting. Quite how the structure is to fit into the intellectual landscape is still uncertain. Whether it will topple over at the first ill wind of counterexample that combines negation with intensionality, remains to be seen. The structure may sag and cave in under the weight of its new ideas and technical terminology, without the buttressing of deep theorems. Or it may just creak at the joints and leak and eventually strike its tenants as uninhabitable.

In Keith Devlin's work, however, regardless of which of these prognoses one favours, situation theory has found an able expositor. He has written

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<sup>1</sup> Bradford Books, MIT Press, 1983.

a very good book indeed,<sup>2</sup> which is bound to become a standard reference in the field. The purpose of this review article is to summarize its contents and to entertain some criticisms along the way. Whether situation theory will survive future tests of linguistic intuition and experiment, strike the would-be convert as enjoying an accessible, elegant and compelling formulation, keep its rich ontology intact, and yield up a worthwhile cull of metatheorems, only time will tell.

The author warns the reader at the outset that the book is not intended to be a work of scholarship. Nor is it intended to be a 'philosophy' or 'linguistics' or 'computer science' text. It is a research monograph on work in progress into a new kind of 'modeling', due mainly to Barwise and Perry, with the overall goal of providing the mathematics needed for the science of information. Devlin believes the modeling should follow *after* the empirical study of information flow and its mechanisms. So he does not think the way lies with extensions of first-order logic. Rather, quoting Rota, he warns that the approach to take might be "shocking to a conservative logician".

Genuinely intelligent systems such as Man do not operate using classical, formal logic; rather they rely upon far more sophisticated mechanisms for processing information. (p. 6)

He gives a standard objection (p. 9) to the conditional connective of classical logic as a rendering of the "if... then..." that occurs in mathematical statements, but does not acknowledge that much has been done by formal logicians, with various relevance logics, to rectify the situation. He also thinks that 'situated reasoning', where information tacitly available in the background is mediating a transition from formally insufficient premisses to a conclusion, reveals a deficiency in standard logic. For in standard logic the emphasis is on formal validity, and enthymemes are not allowed. Devlin clearly wants a notion of argumentative validity or soundness that consists not in the preservation of truth under any and every interpretation, but rather in the preservation of information *within the situation in which the reasoning takes place*.

*Inference* is an activity whereby certain facts (items of information) about the world are used in order to extract additional information (information that is in some sense implicit in those facts). A sound inference is one whose logical structure is such as to support the role of that inference as a link in an informational chain. Truth will be a secondary notion. Classical first-order logic will be a highly restrictive, special case of our theory. (p. 10)

He might have added that the same objection would apply to other logics, such as intuitionistic logic, in which inferential soundness consists in preservation of 'truth' (or 'assertability') value across *all possible interpretations* of a widely specified kind. Formal logic comes out as restrictive because it is too encompassing in its permissible interpretations (or situations of use)

<sup>2</sup> The reader might benefit, though, by reading Chapter 10 *before* Chapter 1.

of the language. Devlin's logic of information will come out less restrictive because it will be more fussy about what counts as a possible interpretation (or situation of use). Interpretations will have to respect various (empirically discoverable) *constraints*.

Information flow is made possible by certain (what will be called) constraints that link various types of situation. *Constraints* may be natural laws, conventions, analytic rules, linguistic rules, empirical, law-like correspondences, or whatever. Their role in the information chain is quite well conveyed by the use of the word *means*. (p. 12)

Smoke means fire. Smoky situations  $S$  carry information about fiery situations  $S'$ :  $S \Rightarrow S'$ . This expresses (or is) a *constraint*. If it has any precursor in the literature, it is Carnap's notion of  $P$ -validity in *The Logical Syntax of Language*, published in 1934.<sup>3</sup> Here ' $\Rightarrow$ ' is not the material conditional, nor is it the turnstile of logical consequence or deducibility in standard logic.

Different agents are capable of extracting different information from the same situation. This is because they are *attuned* to different constraints. Moreover, information is *nested*. Given some, one can extract more. From this the author concludes that information must come in 'large, structured amounts'. (p. 16) It is not unlike a 'bottomless pit', and has a *fractal nature*. Acquiring information involves going from the *analog* environment to *discrete* representations of it: 'from the infinite and continuous to the finite and discrete'. (p. 12)

I am seeking a specific conceptualization of 'information' as a theoretical 'commodity' that we can work with, analogous to (say) the *numbers* that the number-theorist works with or the *points, lines and planes* the geometer works with. ... I shall use Dretske's ideas in order to obtain the kind of precisely defined conceptualization of information we need. (p. 18)

Devlin, like Dretske, regards *cognition* as involving an analog-to-digital conversion. The conversion is effected by the application of *concepts*, or categories. And there is information loss in the process. Our classification of the 'single objects' around us is the one best suited to our purposes. We individuate, recognize and discriminate these objects. Individuated entities are called individuals, and go by the letters  $a, b, c, \dots$ . These will be the *ur-elements* of the set theory that will be used to construct larger situations involving these individuals. They can be individuated, note, by either the agent or the theorist. So we can still model pearl before swine—or can we (see below)? Next we see properties and relations holding of these individuals, and they go by the letters  $P, Q, R, \dots$ . But now, curiously,

<sup>3</sup> This work is missing from the author's short bibliography, whose earliest items are by Shannon in 1949, Wittgenstein in 1953, a *Psychological Reviews* article of 1956, Quine's *Methods of Logic* in 1959, a 1960 monograph by Sperling on brief visual presentations, and an article by Maturana *et al.* in the same year on the anatomy and physiology of vision in the frog.

(j)ust which properties and relations these are is determined by the agent or species of agent. (p. 22)

—and not by the theorist, who may of course belong to a different species. Devlin does not consider the Fregean tradition of thought in philosophical logic and the philosophy of language about the conceptual means for individuation. It appears not to occur to him that individuation may be relative to sortal concepts possessed by the agent but not the theorist. But if this is so then how could the domain of individuals have been agreed upon by both agent and theorist?

$\langle P, a_1, \dots, a_n, 1 \rangle$  is the 'informational item' that individuals  $a_1, \dots, a_n$  stand in the relation  $P$ , and  $\langle P, a_1, \dots, a_n, 0 \rangle$  that they do not. They are the basic informational units of the theory, and are called *infons*. (p. 22) They are *semantic* objects, not syntactic representations. 1 and 0 are the *polarities*. Infons are facts.

Infons, indeed, are but a small embellishment of what Wittgenstein<sup>4</sup> called atomic states of affairs. (The Tractarian doctrine went roughly: The world is all that is the case. What is the case is a collection of facts, not of things. A fact is the existence of a state of affairs. A state of affairs is a combination of objects.) But whereas Wittgenstein remained agnostic about the nature of his 'simples', the situation theorist admits as simples, or as 'basic', the ordinary middle-sized physical objects with which the agent is familiar, as well as all the abstract objects of mathematics about which the agent reasons with any facility.

The situation theorist *also* admits universals on a par with individuals. And they come with sufficiently high adicities, even though they might often be used (in natural language) without all the fillers of their argument places being made explicit. For the philosophical logician there is some wrestling, early in chapter 6, with familiar problems about the true adicity of certain relations, and about sortal restrictions on argument places and whether violations of these leads to falsity or just plain nonsense. Devlin opts for the latter. He also calls infons with all their argument places specified in a sortally correct manner, *saturated*; whereas infons (such as 'John is eating') which are under-specified (compared with 'John is eating steak'; 'John is eating steak now'; 'John is eating steak in New York',...) are *unsaturated*. No attention is paid to the considerable literature on adverbial modification, which might reduce adicities by analysing adverbs of place, time, etc. as sentential operators or as predicates of events rather than as arguments within a predication. Devlin lays down *minimality conditions* on relations. 'John sold' doesn't make sense. 'John sold a house' does. To get an infon out of a relation, then, at least a certain number of argument places have to be filled. Just how many, or which ones, will depend on the relation in question. And unsaturatedness is subject to a condition of

<sup>4</sup> In the *Tractatus Logico-Philosophicus*.

*persistence*: if an infon arises from filling some but not all of the available slots in a relation, then any situation supporting that unsaturated infon must admit of extension to a situation supporting some saturation of that infon—a completely specific one with all the remaining slots filled. It is the minimality conditions that guarantee persistence. (p. 127) Devlin is also exercised by the difference between lack of specificity, on the one hand, and tacit existential quantification on the other. He takes the view (p. 120) that 'John is eating' differs in meaning from 'John is eating something' even though they have the same truth-conditions. He diagnoses the difference in meaning as arising from a difference in topic or focus. In 'John is eating' the focus is solely on John; whereas this is not the case with 'John is eating something'.

The polarities form the set  $\{0, 1\}$  at the present state of development of situation theory. But they are surely a Pandora's box. As in the case of many-valued logic, we can look forward to the day when  $\{0, 1\}$  gets replaced by more meaty mathematical structures, such as  $\{0, \frac{1}{2}, 1\}$  (for indeterminate situation theory), or the closed unit interval (for probabilistic situation theory) or a topology of its sub-intervals (for fuzzy situation theory).

So far the foreshadowed departure from standard logic seems to have taken this form: Start with the formula  $P(a_1, \dots, a_n)$ . Note that it is true in any model  $M$  in which  $\langle M(a_1), \dots, M(a_n) \rangle \in M(P) \dots$ . But this is too 'holistic' or diffuse a condition, involving as it does the whole of  $M$ —we want to focus on what is going on inside  $M$ . So drop parentheses, suppress mention of  $M$ , reify  $P$ , be explicit with a '1' about the positive case (truth) and enclose the lot in double pointed parentheses. Now you have a simple brute fact to work with, called an infon.

These infons can be both abstract, like  $\langle \langle, 0, 1, 1 \rangle$  and  $\langle \langle, 1, 0, 0 \rangle$ , or concrete, like  $\langle \langle$  dies, John F. Kennedy, Dallas, 13 November 1963, 1  $\rangle$ . For the concrete ones, both the temporal instant or interval and the spatial point or region are important. Their size or extent will be appropriate to the kind of agent involved.

By a *scheme of individuation*, I mean a way of carving up the world into the various 'uniformities' that form the basis of our study: individuals, relations, spatial and temporal locations, ...

Such a scheme of individuation will be determined by a particular agent or, more commonly, ... a species of agent. (p. 26)

But (p. 27) we have to distinguish between the *agent scheme* and the *theorist's scheme*. We tend to occupy the latter. And for a non-human agent that we have not ourselves designed and built as an artifact, the agent scheme itself 'at best provides a *theorists's ascription* of a scheme to that agent, one that accords with our observation of that agent'. (p. 27) In general, it is conceded, we have no access to the scheme that the agent actually uses.

One can applaud the author's philosophical sensibility on this point, for it is one that escapes many a scientific theorist who does not pause to consider problems of interpretation, understanding, and the relationship between the objective world and one's subjective point of view. I think Devlin has got it basically right, in a way that makes cross-cultural, interspecific and phylogenetic sense:

... as theorists trying to understand the behavior of some particular agent, we impose upon the world a particular scheme of individuation that we judge to be appropriate to that agent. But, of course, that very act of imposing a scheme is a cognitive act carried out by certain agents in the world, namely ourselves, and consequently is inescapably dependent upon our own individuation capacities. Thus... our standpoint... is essentially a matter of stance not fact. (p. 29)

Agents discriminate situations, perhaps even individuate them, if their perceptual and conceptual apparatus is sophisticated enough. An agent's world is a collection or succession of situations. A situation is a highly structured part of the world: a collection of infons with enough 'mesh' to hang together. (For presumably we do not want to consider unnatural constellations of infons as forming situations. What sort of situation is formed by arbitrarily cobbling together the fact that 0 is less than 1 and the fact of Kennedy's death? We want some kind of homogeneity within the factual variety, to make the infons 'hang together'.)

It is one of the aims of this book to convince you that a potentially useful mathematical theory of information, including the ability to handle the role played by language in the communication of information, is greatly facilitated by the introduction of certain abstract objects, in particular, but not exclusively, infons and situations. (pp. 67-8)

Situations are the theory's way of handling context. (p. 69)

The crucial move in situation theory comes when we allow situations (which are made up of infons) to be constituents of further infons. (p. 31) Thus we have situations containing situations, such as

«thinks, Frege, « <, 0, 1, 1», Jena, 1884, 1»

and

«sees, Oliver Stone, «dies, John F. Kennedy, Dallas,  
13 November 1963, 1», Dallas, 13 November 1963, 0»

An entity might be individuated both as an individual and as a situation. A situation might be directly perceived, and/or thought about. But it does not follow from its being individuated that the agent can describe it exactly.

The ability to *individuate* a 'situation' is a fundamental one that humans, and possibly only humans, come equipped with.... What is new and distinctive about situation theory is that it takes the bull by the horns and tackles this

issue head-on, by admitting situations into the ontology from the very start ... (p. 32)

Presumably in the case of an eye-witness situation of the form

«sees, a, «P, b, l, t, 1», t', l', 1»

we shall have  $t = t'$  and  $l = l'$ , since what one sees is the case then and there. If the situation is one of live television viewing, then  $t = t'$  but not (necessarily)  $l = l'$ . If the situation is one of documentary-film watching, then neither of these identities need hold.

The situation theorist adapts the double turnstile  $\models$  of standard logic so that it no longer means logical consequence between a set of premisses and a conclusion, but rather the relation of *support* between a situation and an infon:  $s \models \sigma$ . If  $I$  is a set of infons all of which  $s$  supports then one writes  $s \models I$ . Devlin also commits situation theory to the metaphysical axiom of realism:

... given an infon,  $\sigma$ , it is a fact of the world that the relation  $s \models \sigma$  either holds or does not hold. (p. 33)

It would be too much of a digression to question the wisdom of adopting this assumption of bivalence. But given the common construal of intuitionistic logic as the logic that preserves information (in the sense of constructive warrant for assertions) I do not think we are compelled to adopt it without at least some metaphysical or meaning-theoretic *argument*. Such arguments, indeed, might counsel the opposite: do *not* assume bivalence!<sup>5</sup> It is worth raising the question here whether there might not be some way of doing situation theory *intuitionistically*, as far as the resulting logic would be concerned, while yet not abandoning the physical realism that informs the theory overall.

There is a maximal situation, the *world*. Thus a *fact* is an infon  $\sigma$  such that  $w \models \sigma$ . We are also told (p. 34) that

... to every real situation  $s$ , there corresponds a particular abstract situation, namely the set

$\{\sigma \mid \sigma \in s\}$ ...

so we may presume that there corresponds to the world its abstract counterpart, which contains as a member each infon that it supports. So let us without further ado think of the world itself as containing each infon that it supports.

Now if

it is a fact of the world that the relation  $s \models \sigma$  either holds or does not hold then when the relation  $s \models \sigma$  does hold, it is a fact of the world that it does—for it would be a strange world that contained disjunctive facts

<sup>5</sup> Cf. my *Anti-Realism and Logic*, Oxford: Clarendon Press, 1987.

without any facts that made either disjunct true. This fact is also an infon, presumably of the form  $\ll \models, s, \sigma, 1 \gg$ . So the world supports it, that is,

$$w \models \ll \models, s, \sigma, 1 \gg;$$

whence  $\ll \models, s, \sigma, 1 \gg \in w$ .

This in turn is a fact, presumably of the form

$$\ll \models, w, \ll \models, s, \sigma, 1 \gg, 1 \gg$$

so the world supports it:

$$w \models \ll \models, w, \ll \models, s, \sigma, 1 \gg, 1 \gg;$$

whence  $\ll \models, w, \ll \models, s, \sigma, 1 \gg, 1 \gg \in w$ .

This in turn is a fact, presumably of the form

$$\ll \models, w, \ll \models, w, \ll \models, s, \sigma, 1 \gg, 1, \gg, 1 \gg$$

so the world supports it:

$$w \models \ll \models, w, \ll \models, w, \ll \models, s, \sigma, 1 \gg, 1, \gg, 1 \gg;$$

whence  $\ll \models, w, \ll \models, w, \ll \models, w, \ll \models, s, \sigma, 1 \gg, 1, \gg, 1 \gg, 1 \gg \in w$ .

This in turn is a fact . . . and the world would appear not to be well founded.<sup>6</sup> And what sort of fact *that* be? This non-well-foundedness is not just an idle curiosity in a theory that nevertheless handles other phenomena in the main intended areas of application. It is rather a core conceptual difficulty in the apparatus the author is proposing. The author records the problem (without explaining in detail how it arises) and simply observes that workers in situation theory accept that they have to adopt a theory of non-well-founded sets.

This, however, is a foundational knock-on effect that should occasion some misgiving. When we try to think about sets *per se*, well-foundedness is an integral part of the conception we arrive at on reflective analysis. Is not situation theory perhaps biting off more than it can chew if it calls for non-well-founded sets? Or are we rather to believe that we may one

<sup>6</sup> Is this what was meant by his saying that information had a fractal nature?

day have to accept non-well-founded sets (despite their initial intuitive unacceptability) simply because they are used in a mature situation theory that has established its empirical and associated *mathematical* credentials by giving a wonderfully illuminating and explanatory account of the phenomena within the domain of its intended application?

It may perhaps be objected in defence of Devlin that I am too swift in assuming the world  $w$  to contain as members the infons that it supports; perhaps the *real* world doesn't really share that feature with its abstract counterpart. To this one can reply that the theoretical apparatus, given its aspirations, should be able to cope with a world that just happens to be wholly abstract, whence identical to its abstract counterpart. Failing that, if one concedes that the real world doesn't really contain as members the infons that it supports, but merely supports them, I suppose there is no insuperable difficulty with the notion that the real world supports infons that have the real world itself as a constituent. Just don't ask me to construe the relation of support set-theoretically, that's all.

But there is a deeper problem looming with any attempt to do semantics with a notion of situation that would have situations' both supporting and being constituents of facts. One can sketch it quite generally as follows. Any finitely specifiable fact will require, for its support, a situation with at most finitely many embeddings of situations within it. But by the same token there is no finite upper bound to the number of embeddings that might be required of a situation in order that it be able to support any chosen fact. (Thus we can have 'John believes the world is round'; 'Mary believes that John believes the world is round'; 'Dick believes that Mary believes that John believes the world is round'; . . .) Given any purported bound on the nesting or internal layering within situations, a convoluted enough fact can always be concocted that such bound situations could not support, for want of the required complexity of embeddings. Presumably, however, we want a semantical correlate of the satisfiability of arbitrary sets of sentences. That is, we want to be able to countenance arbitrary sets of infons, including infinite sets (such as the list I began above), and enquire after situations that support every one of their members. But now if we choose an infinite set  $I$  containing an unbounded crescendo of embeddings within its infons (such as the list referred to), no well-founded situation will be able to support it. Situation theory appears, then, to need non-well-founded sets in general.

Even though the author has been describing real-world situations as infons with constituents, and using set-theoretic terms in doing so, he contrasts *abstract* situations with these *real* situations. Abstract situations are the mathematical constructs built up out of the real-world ur-elements. The real situations are just out there, structured in their own way, a way that is only *modeled* by the set-theoretic structure within those mathemat-



ical constructs. No one-to-one correspondence is assumed between real and abstract situations, because not all abstract situations have any real counterpart. An abstract situation may, for example, contain contradictory or incoherent infons, differing only in their polarities 0 and 1. In any abstract situation  $s$  one has, for every infon  $\sigma$ ,

$$s \models \sigma \text{ if and only if } \sigma \in s.$$

The possibility of incoherent abstract situations motivates the definition of *coherence*, which proceeds as one might expect. Two abstract situations are *compatible* if their union is coherent. An abstract situation is *actual* if the real world  $w$  supports all its infons.

The author devotes some discussion to the ontological credentials of infons (pp. 37 ff). He does not regard them as physically existing. They are abstract objects with which to reason, like various mathematical objects: numbers, groups, fields *etc.* He thinks they are the necessary 'informational objects' required for the development of a mathematical theory of information. With a rather naive<sup>7</sup> neo-Quinean conflation of the nature of numbers and of physical posits, he says (p. 37)

Just as the physicist's particles have to accord with observation of the physical world and the number systems of mathematics have to accord with their intended uses in the world, so too our 'infons' have to fit in with our picture of the way information flows in the cognitive world.

Infons are 'artifacts of a theory that helps us to proceed'.

But this is rather disingenuous. First, he is assuming that we *do* have a pre-theoretic and broadly correct 'picture of the way information flows in the cognitive world'. I for one, I readily confess, do not. Information seems to me to flow down telephone wires, from Kodak slides, from stereo players, from the television screen (hence: from the distant transmitters), from my electronic mail, from graffiti, from friends in the same room, from books, from scratching my head, . . . I simply don't have any single picture of the way information flows, let alone in the *cognitive* world. What's *that*?

In answer to this question the author has some reassuring conjectures:

. . . information is 'carried' or 'arises from' a representation (by way of certain constraints). Without some form of representation, there can be no information. But just because the information cannot 'exist' without the representation, it does not follow that the representation is all there is—that the information is somehow *contained in*, or *part of* the representation. The information arises by virtue of what I am calling *constraints*, and they are separate from the representation that carries the information. The representation has some form of physical realization—an ink pattern on paper, an electro-chemical configuration in the brain, an optical or magnetic pattern on a disk, a sound

<sup>7</sup> or perversely sophisticated

wave in the air, a sequence of electrical pulses in a wire, or more generally *any configuration of objects in the world*. (p. 39; my emphasis)

This strikes me as too cavalier. *Any configuration of objects in the world?* So what is it that gets physically realized in this way then? *Information?* Why not rather an omnipresent God's inexplicable urge to have mereologically patchy physical manifestations?

That it really does all come down to the constraints is obvious when we consider how

an ink pattern on paper, an electro-chemical configuration in the brain, an optical or magnetic pattern on a disk, a sound wave in the air, a sequence of electrical pulses in a wire

would contain information, and what that information might be, if we happened on these things in some distant galaxy on a planet inhabited by physiologically exotic aliens. Now sound waves in the air might be from a volcanic explosion, say, or from some attempt at verbal communication. In the former case, given some geophysical theory of planetary formation in the background, one might extract from the bang the information that lava is on its way. Here the constraints are provided by some versatile background theory that applies not just on *earth* but on the alien planet too. In the latter case, however, where the sound waves are made by *them* as they say something (we know not what) to *us*, the extraction of 'information' is a much more complicated affair. One would need a large body of evidence *and hypotheses*, about the creatures' goals, reproductive physiology, resource consumption, perceptual mechanisms, linguistic syntax—plus some methodological principles such as the assumption that they are reasonably rational and that their actions should be intelligible—before one could even begin to interpret their 'utterances' and thereby uncover the information they convey. Devlin shows some awareness of this when he concedes that

the information is *not* the representation, it is something that results from the combination of the representation *and the constraint*.

Thus we see that the theory of constraints here turns out to be what the modern philosopher, after Davidson, calls the theory of radical interpretation, and what used to be called pragmatics—the theory of how speakers use their words and with what effect. It is this theory that gives us, ultimately, the (linguistic) information that may be contained in certain of the 'configurations of objects in the world' that might be the vehicles for its transfer.

. . . relative to two linguistic constraints, one pertaining to the English language and the other to German, utterances of the two sentences

*It is cold*

*Es ist kalt*

both represent the same item of information . . .



One could not have a clearer admission of the shape of the problem. Want to know what the English sentence means?—then find the constraints pertaining to the *English* language. Want to know what this German sentence means?—then find the constraints pertaining to the *German* language.

Infons are actually not that primitive. They end up, on the author's treatment, being equivalence classes (cf. p. 40), after modding out via the equivalence relation 'denotes the same item of information':

Information... arises by way of intentional representations in cognitive devices such as the brain. A particular cognitive state represents a certain piece of information by means of a constraint. Effective communication between cognitive agents requires that there be an empirical equivalence relation between two representations, an equivalence that can best be described as 'representing the same item of information'. If you factor out the set of all representations by this equivalence relation, the equivalence classes you obtain are what I call the infons—the 'fundamental items of information' of the theory. (p. 66)

There is not very much new in this. But with the new terminology it may look new. To see how familiar the idea is, consider a paraphrase in more familiar philosophical terminology:

Meanings, or propositions... arise by way of intentional representations, these being sentences of a public language or sentences of Mentalese in cognitive devices such as the brain. A particular cognitive state (tokening a sentence of Mentalese or of a public language) represents a certain state of affairs by means of an intentional relation. Effective communication between speakers requires that there be an empirical equivalence relation between two representations, an equivalence that can best be described as 'representing the same state of affairs'. If you factor out the set of all representations (in Mentalese or a public language) by this equivalence relation, the equivalence classes you obtain are what I call the propositions—the 'fundamental semantic items' of the theory.

Devlin's project is therefore based on an unargued rejection of all the arguments that have dominated analytical philosophy over the last three decades, to the effect that propositions (meanings) do not exist and that meaning is indeterminate. Indeed, one of the well known passages in Quine's *Word and Object* expresses his thesis of the indeterminacy of translation by saying that rival translation manuals, each equally well supported by all possible behavioural evidence, will translate some sentence of Junglese into two different English sentences that 'stand in no plausible relation of equivalence, however loose'. The assumption that Devlin accepts uncritically—that effective communication between speakers requires that there be an empirical equivalence relation—has long been abandoned by most philosophers of language under the influence of Quine's attacks on exact translatability, on synonymy and on the analytic/synthetic distinction. Now whether they are correct in abandoning it is a deep and no doubt still controversial matter. It is heartening to see someone launch into the formal development of a theory that cocks a snook at the dominant philosophical

orthodoxy. One can only wish him good results in doing so. As he himself says,

... the step from the individuals, locations, relations and infons to the situations requires a definite commitment to dealing with entities that can only be understood *in terms of the system that thereby results*. (p. 73)

Devlin gives an engaging discussion of the way in which natural, rational, real and complex numbers are modeled by means of different definitions within set theory, and stresses that they are part of the common domain of abstract objects in the world of Man. The fact that they can be constructed or defined or modeled in different ways does not impugn their status as intentional objects, constructs of the human intellect. (This of course is philosophically tendentious, but let us grant Devlin his point. I am more interested at present in the analogy that he is going to make with infons.)

... an infon is defined to be an equivalence class of a pair  $\langle R, C \rangle$  of a configuration,  $R$ , and a constraint,  $C$ . This assumes an agent-discriminated (and theorist-individuated) notion of equivalence that two pairs  $\langle R, C \rangle$ ,  $\langle R', C' \rangle$  'give rise to the same item of information'. We do not attempt (here) to reduce this equivalence relation to anything more 'basic', any more than we try to define the other uniformities in our theory. We simply take it as one of the starting points for any theory of information that there is *something* that can arise from a combination of a configuration and a constraint that is not necessarily unique to that particular pair. We objectify that 'something' as an infon.

This process is no more circular than any of the number system constructions described earlier, and indeed the analogies are good ones. (p. 47)

On closer scrutiny, however, the analogies are very weak. And it is no good citing points of analogy and ignoring major points of disanalogy. Complex items brought into theoretical ken by construction out of, or by definition in terms of, simpler items are only acceptable if the latter are. Now in the case of the number systems, one can give a very convincing account of natural numbers as *primitive logical objects* (not necessarily as classes of classes). Then the rationals can be defined as equivalence classes of pairs of naturals; and the reals as either Cauchy sequences of rationals or Dedekind cuts of the rationals. Man has been able to do all the rest only because God gave us the integers!

But have we been given in the same clear way the *configurations* and the *constraints* out of which Devlin seeks to construct infons? And is the equivalence relation he invokes—'gives rise to the same item of information as'—as clear and objective as the equivalence relations involved in the definitions of the rationals in terms of the naturals, and of the reals in terms of the rationals? Given that the constraints of which he speaks cover just about every hoary topic of a metaphysics curriculum, from analyticity through to causality, I think the answer is negative.

This is not to say that the theory will be without merit in its eventual



basic type is an object type. In particular this is true of the basic type *SIT*. There are also non-basic *situation types*, like the type of game situation in which the San Francisco 49ers are winning, or the type of situation in which someone is running at some location and at some time. In general such a non-basic situation type is of the form  $[\dot{s}|s \models I]$  where  $I$  is a set of infons. It classifies a situation in terms of its internal structure, rather than typing it from the outside. (p. 60) If  $I$  involves parameters, then  $[\dot{s}|s \models I]$  is a *parametric situation type*.

... situation *types* are definite, higher-order uniformities across situations that are discriminated, if not individuated, by cognitive agents such as ourselves, and presumably a great many other animals and cognitive devices as well. (p. 59)

Non-parametric infons, or 'states of affairs' are the basic items of information about the world; parametric infons are the basic units our theory uses in order to study the transmission of information. (p. 123)

There is also object-type abstraction, producing parameters ranging over non-basic types of individual.

If  $\dot{x}$  is a parameter and  $I$  is some set of infons (in general involving  $x$ ), then there is a type

$$[\dot{x}|s \models I]$$

the *type* of all those objects  $x$  to which  $\dot{x}$  may be anchored in the situation  $s$ , for which the conditions imposed by  $I$  obtain. (p. 60)

$x$  is said to be the *abstraction* parameter and  $s$  the *grounding* situation for this type. It is always assumed that there is enough situational determinacy to provide the ultimate anchorage for a parametric object or situation type. If necessary, one resorts to another situation, called a *resource* situation, to supply the missing hook-ups of parameters to objects.

The contrast between classifying a situation in terms of its internal structure, rather than typing it from the outside, becomes clear with the following two examples. Here we classify a situation in terms of its structure, because the abstraction parameter  $SIT_1$  occurs to the left of  $\models$  in the condition:

$$[SIT_1|SIT_1 \models \langle\langle \text{running}, IND_1 \{ \langle\langle \text{person}, IND_1, 1 \rangle \rangle \}, LOC_1, TIM_1, 1 \rangle \rangle]$$

This is the type of situation in which some person is running at some location and at some time. Now let  $s$  denote 'Jon's environment (over a suitable time span)'. Then the following is the type of all those situations that Jon sees within the given situation  $s$ :

$$[SIT_1|s \models \langle\langle \text{sees, Jon}, SIT_1, LOC_1, TIM_1, 1 \rangle \rangle].$$

Note that here the parameter  $SIT_1$  appears not to the left of the turnstile, as the supporter, but embedded within the supported infon. Thus the

situations seen by Jon have been typed 'from the outside' (albeit within the given situation  $s$ ).

... this is a case of an object-type that is a type of situation. (p. 60)

An *infonic proposition* is a claim of the form  $s \models I$  where  $s$  is a situation and  $I$  is a set of infons. (p. 63) Abstraction on the left gives situation types, like the former example above; abstraction on the right gives object types (including ones like the latter example above). Situations, individuals, locations, times, relations, and parameters are all of various types, and they are the constituents of infons. Situations combine with infons to produce propositions (of the form  $s \models I$ ) from which abstraction yields the types of those situations, individuals, locations, times, and relations.

Suppose  $\Gamma$  is collection of parametric infons, called a *set of issues*. A  $\Gamma$ -*infon* is any infon that results from anchoring the parameters in  $\Gamma$ . Devlin believes that it is possible to isolate the  $\Gamma$  *oracle* of an individual—a 'complete world chunk', so to speak, in which the individual in question is embedded:

Given an individual (animate or inanimate) or a situation  $a$ , the  $\Gamma$ -oracle of  $a$ ,  $Oracle_{\Gamma}(a)$ , is the situation comprising that part of the world and the entire 'body of knowledge' that, within the framework provided by  $\Gamma$ , concerns  $a$ . That is to say,  $Oracle_{\Gamma}(a)$  is the 'minimal' situation,  $s$ , such that

$$s \models \sigma$$

for any factual, parameter-free  $\Gamma$ -infon,  $\sigma$ , that 'genuinely' involves  $a$ .

In order for an oracle to be less than (that is, a proper part of) the world itself, it is important that it be defined relative to a set of issues ( $\Gamma$ ) that circumscribe or limit the terms in which the individual  $a$  may be described.<sup>8</sup> Otherwise, in the case of a physical object  $a$ , we might, given enough spatio-temporal relations, be able to bring the whole world into the oracle of  $a$ . The oracle is to be the *minimal* situation supporting the  $\Gamma$ -infons that genuinely involve  $a$ . As far as  $a$  is concerned, its  $\Gamma$ -oracle is the world, insofar as the latter is specified using only the resources within  $\Gamma$ :

If the only kind of information available is that provided by the set of issues  $\Gamma$ , then, starting with the object  $a$ , there is no way to distinguish  $Oracle_{\Gamma}(a)$  from  $w$ , the world. For any  $\Gamma$ -infon  $\sigma$  in which only objects that are constituents of  $Oracle_{\Gamma}(a)$  occur,

$$Oracle_{\Gamma}(a) \models \sigma \text{ if and only if } w \models \sigma.$$

Thus  $Oracle_{\Gamma}(\text{Keith Devlin})$ , for the sort of set  $\Gamma$  of issues that we would normally take to concern Keith Devlin, would not involve any information

<sup>8</sup> The reader may well be puzzled as to why the relativizing set of issues does not appear in connection with Keith's oracle on p. 233.

about Alpha Centauri. But if  $\Gamma$  were to contain infons involving astronomical objects and a childhood interest of his in star-gazing, then Alpha Centauri might well find its way into his oracle. It is only with one's  $\Gamma$ -blinkers on that the oracle of  $a$ , from the point of view of  $a$ , looks to be the whole world that  $a$  inhabits.

The philosophical reader will be familiar with the conceptual analysis of meaning provided by Paul Grice in a series of famous papers from 1957 onwards. Grice distinguished between natural and non-natural meaning. Examples of natural meaning are 'Those clouds mean rain' and 'Smoke means fire'. An example of non-natural meaning is 'By uttering the sentence 'It's cold outside' John meant that it was cold outside'. Linguistic meaning importantly involved speakers' intentions to induce beliefs in listeners by means of their recognition of that very intention.

The situation theorist, by contrast, is more interested in restoring what is *common* to cases of natural and non-natural meaning, than in finding a complex condition involving reciprocal attitudes that set apart cases of linguistic meaning from all others. One might draw an analogy here with wave mechanics. The wave equation governs wave phenomena in a great variety of media. There are sound waves, electromagnetic waves, waves in water *etc.* The underlying mechanisms vary in each case. But the mathematics of the wave equation and its solutions under different boundary conditions bring out what is common in this variety of wave phenomena.

For the situation theorist, by analogy, there is an interesting underlying *unity* in cases of both natural and non-natural meaning. In all such cases there is (potential) information transfer. Situations of one kind *mean* a situation of another kind, because of some connection between them. For example, a situation in which there is smoke means a situation in which there is fire, because of the nomic connection between fire and smoke. A situation in which a bell rings means a situation in which schoolchildren break for recess because of the conventional connection (to which the hearers are attuned) between bell-ringing and breaking for recess. A situation in which someone utters 'Here is a cookie' means a situation in which a cookie is present and on offer because of the linguistic conventions (to which speaker and hearer are attuned) according to which any situation of utterance of 'Here is a cookie' is a reliable indicator of a situation in which a cookie is present and on offer.

This talk of situations should, strictly speaking, be of situation *types*. The connections between situation types adverted to in the examples above are called *constraints*. As the examples show, constraints may be based on natural laws or on human conventions. Whoever knows the laws or conventions involved is said to be *attuned* to them. In this way situations of the former kind can *mean* situations of the latter kind. For the former type of situation ( $S_0$ ), via the constraint in question, *involves* the latter

type of situation ( $S_1$ ):

$$S_0 \Rightarrow S_1.$$

In fact, the constraint is this latter involvement, concerning the two parametric situation types

$$S_0 = [s_0 | s_0 \models \langle\langle \text{smoke-present}, LOC_1, TIM_1, 1 \rangle\rangle],$$

$$S_1 = [s_0 | s_0 \models \langle\langle \text{fire-present}, LOC_1, TIM_1, 1 \rangle\rangle].$$

These are parametric because of their 'unbound' occurrences of  $LOC_1$  and  $TIM_1$ . The constraint governing them can itself be expressed as a fact, namely a *parameter-free* infon:

$$\langle\langle \text{involves}, S_0, S_1, 1 \rangle\rangle$$

in which the free occurrences of those parameters have somehow been bound; and it is to *this* that agents are 'attuned'.

The account proceeds along similar lines for linguistic meaning. The linguistic meaning of a sentence is identified with a conventional constraint, a constraint according to which any utterance situation of that sentence *involves* (in the technical sense above) situations of the type described by the sentence. Thus the sentence

HERE IS A COOKIE

has as its meaning the constraint

$$S_0 \Rightarrow S_1,$$

where

$$S_0 = [s_0 | s_0 \models \langle\langle \text{says}, PERSON_1, \text{HERE IS A COOKIE}, LOC_1, TIM_1, 1 \rangle\rangle]$$

is the utterance situation type and

$$S_1 = [s_1 | s_1 \models \langle\langle \text{present}, COOKIE_1, \text{HERE IS A COOKIE}, LOC_1, TIM_1, 1 \rangle\rangle]$$

is the described situation type. To get actual situations from these situation types (so that a listener who knew the meaning of *HERE IS A COOKIE* would in virtue of *that* linguistic knowledge know what meant what), the (restricted) parameters  $PERSON_1$  and  $COOKIE_1$  and the basic parameters  $LOC_1$  and  $TIM_1$  would have to be anchored. And it is important that the parameter  $LOC_1$  anchor to the *same place* in both of those situations; and that the parameter  $TIM_1$  anchor to the *same time* in both:

The actual choice of parameters is not important. The parameters merely keep track of certain *linkages* between the two types. The *meaning* of the sentence is the composite connection between the types, a constraint, and as such it is a holistic entity that does not involve parameters. The parameters only appear when we *pull apart* the meaning into two separate types, the type of the utterance and the type of the described situation. (p. 123)

This conception of the meaning of a sentence type as consisting in a mapping from its tokenings, within a context, to a context-relative proposition or truth-condition, is not new. What we have here is the expected formalization of the idea in situation theory. It remains to be seen how situation theory can also model the phenomenon of *combination* of meanings. How, that is, do meanings of words combine to produce meanings of larger expressions (such as sentences) in which they occur?

Perception of, or thought about, the world involves mental states. Devlin uses the notation  $\#S$  to denote mental situation types.

In order for an agent... to be able to discriminate situations of type  $S$ , there must be a type  $\#S$  of mental state that, under normal conditions, excluding hallucinations and the like, means (in the sense of the relation *involves*) that there is a situation of type  $S$ .

That is, there must be a factual constraint  $\#S \Rightarrow S$ . The factuality of constraints of this form is clearly one of the requirements that must be satisfied by any agent that may be classified as cognitive. (pp. 99–100)

We are now in a position to discuss attunement of agents to constraints (p. 100). An agent is *attuned* to constraint  $C = [S \Rightarrow S']$  just in case the agent can discriminate  $S$  and  $S'$  and has the corresponding mental states  $\#S$  and  $\#S'$  and itself embodies ('in its own mind') the constraint  $\#S \Rightarrow \#S'$  in such a way that the following diagram commutes:

$$\begin{array}{ccc} S & \Rightarrow & S' \\ \uparrow & & \downarrow \\ \#S & \Rightarrow & \#S' \end{array}$$

The agent sees a situation of type  $S$ . This 'creates' in the agent a corresponding mental state of type  $\#S$ . This in turn, via the constraint  $\#S \Rightarrow \#S'$ , 'gives rise to' a mental state of type  $\#S'$ . The real-world constraint  $[S \Rightarrow S']$  'then enables (the agent) to conclude correctly that there must in fact be (a situation of type  $S'$ )' (p. 100; setting aside the physical realism, this is of course Hume's well known account of our habit of mind in thinking causally). Devlin then gives a delightfully engaging discussion (in chapter 4, section 5) of a robot *SID*, a simple illustrative device, to show these ideas in action, and to bring to light the need to distinguish between *knowing that* and *having the information that*. The theme is taken up again on pp. 129–30 when he discusses the mental abilities of monkeys able to discern that rectangle  $A$  is larger than  $B$ , which in turn is larger than  $C$ , but

not able to discern that  $B$  is intermediate in size between  $A$  and  $C$ . Yet the latter information is implicit in the former, or, in Devlin's terminology, *nested* in the conjunction 'A is larger than B and B is larger than C'. The monkey somehow *has* this information, but does not *know* the fact in question. (Perhaps the slave boy in Plato's *Meno* was a reincarnation of such a monkey?) The moral to be drawn from this is that the rule of conjunction introduction is a conceptual extra that has somehow to be evolutionarily acquired (in the case of animals) or built in by design (in the case of artificial beings). One does not have by default a grasp of  $P \& Q$  even when one has a grasp of  $P$  and a grasp of  $Q$ . Grasp of logical complexity requires an elaboration of 'neural' architecture (natural or artificial) beyond that required for the grasp of constituents. One may be able to traffic primitively with infons without being able to deal with logical compounds composed out of them. This distinction between the theorist's logic and that of the agent can be exploited to design artificial agents that can handle information flow only up to the level of logical complexity required by the tasks they have to handle.

Devlin introduces conjunction and disjunction as operations on infons in the way one would expect. The familiar truth tables for those operations are translated straightforwardly into conditions on the support by a situation of the compound and its constituents. One might say that disjunction and conjunction are 'support conditional' operators. Existential quantification, likewise, requires only a translation of the usual Tarskian satisfaction condition into the new language of infonese:

If  $\sigma$  is an infon, or compound infon, that involves the parameter  $x$  and  $u$  is some set, then

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

is a compound infon, and for any situation,  $s$ , that contains, as constituents, all members of  $u$ :

$$s \models (\exists \dot{x} \in u) \sigma \text{ if and only if there is an anchor, } f, \text{ of } \dot{x} \text{ to an element of } u, \text{ such that } s \models \sigma[f].$$

These logical compounds involve *infons*. Unlike Barwise and Perry,<sup>9</sup> Devlin does not allow logical combinations of *types*, for the reason, as he puts it, that

Agents that are capable of individuating types do not manipulate them logically the way they do, say, sentences. Rather they simply individuate them as uniformities across their environment. Thus any logical structure in a type is essentially *internal* to that type, that is to say, *prior* to its abstraction as a type. Thus it is at the informational level of infons and compound infons that the combinatory logic is appropriate. (pp. 141–2)

<sup>9</sup> *op. cit.*

But, one might object, if the agents Barwise and Perry do it, shouldn't we be able to model it? For is not situation theory aspiring to be a theory of the way cognitive agents *in general* handle information and its flow according to its logic? Either we must reveal some incoherence in compounding types themselves, or (on pain of having a theory of insufficient scope) we are obliged to provide for such compounding as a distinct possibility for cognitive agents that might wish to push such a line, should they be appropriately tuned.

The exposition of the 'logic of infons' is rather unsatisfying because it is so incomplete. At least the following question should have been answered: how does that part of the logic of infons that deals with straightforwardly 'extensional' relations compare with standard first-order logic? Does anchoring correspond straightforwardly to assigning individuals to free variables? Are infons the straightforward correlates of literals (atomic formulae or their negations)? Is support of an infon (by a situation, relative to an anchor) the straightforward correlate of satisfaction of a formula (within a model, relative to an assignment of individuals to free variables)? Does support of a non-parametric infon correspond to truth? What would be the infonic counterpart of the standard relation of logical consequence? What, indeed, would be the basic rules of natural deduction that might be licensed within infonic logic? Is there any interest in having a sound and complete system of proof for infonic logic? If infonic consequence is 'situated' and therefore essentially different from standard logical consequence, what are the objections in principle to its being captured by standard logical consequence *modulo* some theory that expresses, by means of appropriate sentences, the constraints governing information flow? (This question underlines the need to *exalt* the primitives and the varied apparatus of situation theory). Finally, how do the meanings of words (as modeled within situation semantics) combine to form meanings of sentences in which they occur? (A very important question which, at p. 232, the author says he will not try to answer.) These and many other questions are ones for which readers will have to seek answers on their own.

There are two main directions in which situation theory reaches out beyond the extensional semantics of first-order logic. The first is by dealing with the *efficiency* of natural language. Natural language is efficient because its sentences, by virtue of contained indexicals, can be used in different situations to make different statements. By modeling the situation of utterance and providing restricted parameters as interpretations of indexical expressions, situation theory deals with this feature well.

The second aspect of natural language which situation theory aspires to model is its apparatus for attitudinal ascription. It is, after all, the beliefs and desires of a cognitive agent that guide its behaviour in the world as it perceives it. It soaks up information to form beliefs, and acts on that

information to satisfy its desires. And for a social creature, such information often, and very importantly, concerns *others'* beliefs and desires. And much of this information is conveyed by the language of mental states, by *attitudinal ascription*. So situation theory must be able to model the flow of information involved in attitudinal ascription. Even if we were aiming to build robots capable both of independent exploration of the world and of independent actions in pursuit of their goals, then provided that we wanted them to be able to exchange information in a co-operative way, so as to be able to anticipate each others' actions, we would have to equip them with an 'understanding' of the language of mental states, both appetitive and cognitive.

The language of mental states, however, provides intensional contexts giving rise to well known logical difficulties. Unfortunately, despite his broadly satisfactory account of the rôle of the attitudes in the life of a rational agent, Devlin does not give the reader who may have little background in philosophical logic much appreciation of the full gamut of logical problems concerning intentional discourse. These problems involve the distinction between *de re* and *de dicto* attitudinal ascription; ranges of quantification; the non-committal nature of the attitudes (undecidedness and indifference); coherent but mistaken beliefs about identity and distinctness; self-conscious belief; logical myopia; the relations among the various attitudes; and constraints of ideal rationality on the attitudes.

In chapter 6, on mental states, Devlin gives only the flavour of situation semantics for the attitudes. It is not enough to see how the theory would fare against the tests given above, but it is an interesting and provocative foray. His main concern is with a problem in the vicinity of the fourth on the list in the previous paragraph, the well known Kripke puzzle<sup>10</sup> concerning the Frenchman Pierre, who in Paris acquires from friends' conversation the belief that

*Londres est jolie*<sup>11</sup>

and later, on visiting London, and learning English, comes to believe that London is not pretty

The problem is that we do not wish to convict Pierre of irrationality, but the 'external contents' of these two beliefs contradict each other. One has it that the city of London is pretty, the other that it is not. But this is to neglect the 'internal' structures of these beliefs. On Devlin's account, Pierre has two 'notions' of London, which in situation semantics will occur as constituents in the internal structure of the beliefs we attribute to Pierre. Corresponding to 'Londres' is the notion  $L_1^{\#}$  and corresponding to 'London' is the notion

<sup>10</sup> Kripke, S. A., 'A puzzle about belief', in A. Margalit (ed.), *Meaning and Use*, Dordrecht: Reidel, 1979, pp. 239-283.

<sup>11</sup> which Devlin renders as '*Londres is pretty*', which jumps the gun a bit on the deeper problem that Kripke wanted to pose about translation.

$L_2^\sharp$ . Since these are distinct (and Pierre lacks the belief that one might crudely express by ' $L_1^\sharp = L_2^\sharp$ ') he is not guilty of self-contradiction. Devlin would saddle him with two distinct beliefs having the following internal structures, where  $s^\sharp$  is Pierre's notion of his situation at large:

$$\langle \text{Bel}, s^\sharp, \text{is\_pretty}^\sharp, L_1^\sharp, \text{now}^\sharp, 1 \rangle$$

$$\langle \text{Bel}, s^\sharp, \text{is\_pretty}^\sharp, L_2^\sharp, \text{now}^\sharp, 0 \rangle$$

Note here how the polarity of 0 is used to render the negation of the predicate.

Each of the 'notions' in Pierre's cognitive world is *of* a thing in the real world. His notion  $s^\sharp$  is *of* that part of the real world that counts. Perhaps his notion  $\text{is\_pretty}^\sharp$  is his impression of the Fregean sense *of* the English expression 'is pretty' (Devlin gives little guidance on this score). Pierre's notions  $L_1^\sharp$  and  $L_2^\sharp$  are, *for Pierre*, as of distinct cities (they have to be—on pain of contradiction-for-him) but in reality they are *of* one and the same city, London.

The *external contents* of Pierre's two notionally distinct beliefs, however, are one and the same:

$$s \models \langle \text{is pretty, London, now, 1} \rangle$$

Thus we see how in situation theory we model the way the attitudes hook onto the world, but in cranially idiosyncratic ways. Agents can have their own misinformed but consistent cognitive worlds that nevertheless give a good enough picture of the world outside for them to function within it. From the third-person standpoint, in reporting what is going on within their cognitive worlds, we are *both* making those cognitive worlds *part of* the real-world-for-us, *and* articulating the *connections between* those cognitive (notional) worlds and the real world that *they* are trying to hook onto. By making situations out of stretches of the real world, and the cognitive worlds of agents, and allowing situations to be embedded within situations, situation semantics is equipped to account for *iterated* attitudes and their ascription. When we look at a belief, say, as connecting with the world, we are interested in its *propositional external content*; when we try to account for it as it is for the believer, so to speak, we are interested in its (notional) *structure*.

Thus in general, any intentional state (such as a particular belief or desire) involving a single infon has both a propositional external content and a (notional) structure. (p. 172) These are, respectively,

$$s \models \langle R, a_1, \dots, a_n, i \rangle$$

and

$$\langle M, s^\sharp, R^\sharp, a_1^\sharp, \dots, a_n^\sharp, i \rangle$$

where  $M$  is the psychological mode (belief, desire...),  $i$  is the polarity, and the sharped items are the agent's idiosyncratic notions.

With the theoretical notion of external content available, Devlin ventures the following analysis of knowledge (p. 183):

*Knows*( $a, p, t$ ) holds if and only if, at time  $t$ , agent  $a$  has a belief,  $B$ , whose external content is  $p$ , and  $B$  was either caused by, or else causally sustained by,  $a$  acquiring the information that  $p$  at some time  $t'$  prior to  $t$ .

This is an interesting proposal, since it makes knowledge a relation rather than an intentional state. But it seems to face a problem. Hegel did not know that the number of planets is greater than 7. But he did know that 9 is greater than 7. Now Hegel might have suffered a quirk of wiring that caused him, on learning that 9 is greater than 7, to acquire the *belief* that the number of planets is greater than 7. (This could happen without Hegel even acquiring the belief that the number of planets is 9!) So:

at time  $t$  (shortly after writing *Phänomenologie des Geistes*, say) Hegel has a belief  $B$  (that the number of planets is greater than 7), whose external content is  $p$  (*that 9 is greater than 7*), and  $B$  was caused by Hegel acquiring the information that  $p$  at some time  $t'$  prior to  $t$ .

On Devlin's analysis, then, Hegel *knows* that the number of planets is greater than 7. But he doesn't! In this counterexample, I am assuming that the belief

$$9 \text{ is greater than } 7$$

and the belief

$$\text{the number of planets is greater than } 7$$

have the same *external content*, namely

$$w \models \langle \text{>, 9, 7, 1} \rangle.$$

Now it might be objected that the latter belief's external content should be represented not with 9 in the first place for an individual within the infon, but rather with a *restricted parameter* that will anchor to whatever number happens to be the number of planets (namely, 9). Thus the suggestion would be that the external content of

$$\text{the number of planets is greater than } 7$$

is something more like

$$w \models \langle \text{>, } IND_1 \mid \langle \text{numbers the planets, } IND_1, \text{now, 1} \rangle, 7, 1 \rangle$$

But if this more sophisticated stipulation of external content has to be resorted to in order to avoid this puzzle about Hegel's numerical knowledge



and astronomical belief, why does Devlin say that the external contents of Pierre's two beliefs about London conflict? Why not similarly demur at the insertion of *London itself*, intentionally unalloyed, into the argument slot after 'is pretty'? Why not insist on restricted parameters—one for London, another for *Londres*—in the infonic rendering of the external contents of Pierre's beliefs? (This would take us even further in absolving Pierre of any logical self-contradiction.) It would appear that Devlin is not in a position to give uniform solutions to the problems of Hegel and Pierre.

My earlier queries about the logic of infons can be posed with even greater urgency for the logic of intentional discourse. *Is* there such a thing for actual agents? Or is it possible to have an intentional logic only for highly idealized agents that are not even allowed to be logically myopic? What would such an ideal, normative logic of belief be like? How does the semantics on offer vindicate its basic rules of inference?

If no such logic is forthcoming—neither for actual agents, nor even for highly idealized ones—then just what does all the semantical machinery accomplish? If it has been put in place in order to solve some logical puzzles with intentional discourse, then why not address *all* the well known problems in this area in one fell swoop? Even after doing the latter, what further help does it offer if there is no system of logical inference to accompany it, and no soundness, completeness and compactness metatheorems to be had? Of what use will this rather complicated semantics be in the design of artificially intelligent agents?

Limitations of space prevent further detailed consideration of the author's treatment of other topics such as negation and conditionals. The reader will find interesting treatment, in Chapter 7, of the visual content of visual experience, and thought-provoking discussion of the interplay between seeing, seeing that, and believing. Chapter 8 sketches how situation semantics would deal with indexicals, proper names, common nouns, verbs, tense, singular noun phrases, anaphora, and attributive uses of definite and indefinite descriptions. By this stage the reader will be impressed by how the stock of concepts built up admits of reasonably straightforward application to each of these varied logico-grammatical phenomena. Moreover, by distinguishing among utterance situation, embedding situation, resource situation and described situation, the situation theorist is able to say useful things about the different kinds of speech act in Searle's well-known taxonomy. Quantification, negation and conditionals receive brief treatment in chapter 9.

By and large the discussion in these chapters remains sketchy and expository. The author succeeds in translating into the terminology of situation theory various basically sound intuitions about visual experience, about belief and about the functioning of these other main features of natural language. One looks forward now to having systematic results or applica-

tions (especially, say, in the design of artificial intelligence) that will make all this labour of terminological paraphrase worthwhile.

A problem area that is exercising many contemporary philosophers is that of *normativity*. Every modern logician knows how the current tradition was born with Frege's anti-psychologism in logic. With Frege we adopted the view of logic as the science of inference between objective contents, or *thoughts*, that were not tinged with psychological idiosyncracies from individual thinkers. Rather, thoughts inhabited an objective 'third realm'. They were the publicly accessible contents of declarative sentences. They were as ideal and abstract and eternal as, say, the natural numbers. And logical laws were imbued with a *necessity* that transcended any influences that might extend from empirical investigations of the world. Logic was held (and *is* held, by many a contemporary philosopher of logic) to be both *a priori* and *analytic*. The soundness of inferences was a matter for the rational intellect to decide, without recourse to facts about the physical world (including facts about how information actually flows). And the soundness of inferences resided in the *meanings* of the logical operators involved. Because these meanings were objective and could be grasped by any thinker, the thinker was bound to submit to the normative demands of logic.<sup>12</sup>

By contrast with this view, Devlin urges us to take the view that the logic of information is at least in part a matter for empirical investigation. It does not become clear in reading his text just how he would conceive of the normative character of logic. Would logical rules of inference simply be high-level theoretical generalizations, vulnerable to revision in the light of empirical discoveries about information flow? Avenarius once had such a view: for him, the laws of thought would arise from the fact that the flow of physiological energy underlying human cogitation obeyed the least action principle! But is the eventual *philosophical* picture on offer from situation theory (as presented by Devlin) really that naive?

In conclusion I would like to make some broader connections between situation theory and other areas of logic and metaphysics.

• *Ideal types and normativity*

Devlin does make much of ideal types, stressing repeatedly that situation types are abstract, ideal additions to an ontology that has already, on similar grounds of theoretical success and convenience, been expanded to include numbers, ideal geometric objects and highly theoretical physical posits such as quarks. The reader intrigued by the philosophical implications, for logic, of situation theory might wish to consult Brian Ellis's recent book *Truth and Objectivity*, for a physicalistic account of the normativ-

<sup>12</sup> —once the 'correct logic' had been identified upon reflective analysis! In *Anti-Realism and Logic, op.cit.*, I argued that the correct logic on this view is *intuitionistic relevant logic*.

ity of logic as arising from the *ideal structure* of rational belief systems.<sup>13</sup> There must be room for a notion of an agent's being able, and reprehensibly so, to *botch* the flow of information; of being able, and reprehensibly so, to commit *fallacies* of reasoning even when apprised of all relevant physical facts. This is a further metaphysical and epistemological project that can be undertaken once the details of situation theory have been hammered out. But it could provide a guiding perspective even when developing those details.

• *Situation theory and intuitionistic type theory*

Another high-level theoretical connection that one is invited to make is that between situation theory and Martin-Löf's intuitionistic type theory,<sup>14</sup> which has become so important recently in the foundations of computer science. I said earlier that I saw no reason why the situation theorist should be committed to metaphysical realism, bivalence and classical logic. Couldn't (indeed, *shouldn't*) there be a constructive situation theory as well (or instead)? It would be interesting to see whether the main ideas behind Martin-Löf's type theory could be differentiated and extended so as to absorb the new complexities of situation theory in handling the flow of information not only about the abstract realm of constructive mathematics but also about cognitive agents and their thought and communication about the world.

• *Relevance logic*

I remarked above that Devlin seemed unaware of the efforts of many relevance logicians over the past few decades to provide formal systems with relevant implication connectives or with relevant consequence relations that would make better sense of the 'if... then...' connective in mathematics and our logical intuitions concerning its proper use. It strikes me that it would be a special mark in favour of situation theory if it could exploit

- the way infons are constructed from constituents,
- the way situations are nested within situations,
- the way restricted parameters have to be satisfactorily anchored, and
- the way constraints are expressed with special attention to repetition of restricted parameters within situation types,

to give an account of logical consequence between information-bearers that would somehow ensure that argumentative passage, or inference, from one situation (or set of assertions) to another always proceeded *relevantly*. This much is extremely important for the automation of proof search, which will have to be a major component in the design of any artificial agent that can

<sup>13</sup> For a briefer discussion of the shape of the problem, and some different ideas as to its solution, see my 'Logic and its place in nature', in P. Parrini (ed.), *Kant and Contemporary Epistemology*, Dordrecht: Kluwer Press, 1994, pp. 101–113.

<sup>14</sup> *Intuitionistic Type Theory*, Naples: Bibliopolis, 1984.

reason deductively from its beliefs.<sup>15</sup>

With its plentiful stock of technical ideas, its broadly sensible (if ontologically lax) philosophical outlook, and its potential linkages within the larger intellectual landscape, situation theory deserves the attention of talented researchers for a good time ahead.

A conference on the theme  
Truth in Mathematics

will take place in Mussomeli, Sicily, 13–20 September, 1995.

The meeting is intended to be accessible to a wide span of philosophers and mathematicians. The President of the conference is Professor Michael Dummett (Oxford).

Speakers are:

D. S. Bridges (Waikato, New Zealand)	A. Conte (Turin, Italy)
H. G. Dales (Leeds, England)	E. Effros (UCLA, USA)
H. Field (CUNY, USA)	D. Isaacson (Oxford, England)
V. Jones (Berkeley, USA)	G. Lolli (Turin, Italy)
A. Macintyre (Oxford, England)	P. Maddy (Irvine, USA)
Yu. Manin (Moscow and Bonn)	D. Martin (UCLA, USA)
P. Martin-Löf (Stockholm, Sweden)	Y. Moschovakis (UCLA, USA)
G. Oliveri (Leeds, England)	D. Prawitz (Stockholm, Sweden)
T. Slaman (Chicago, USA)	W. Tait (Chicago, USA)
W. H. Woodin (Berkeley, USA).	

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<sup>15</sup> For a discussion of the shape of the problem and some different ideas as to its solution, see my *Autologic*, Edinburgh: Edinburgh University Press, 1992.