Situated Information Flow

Introduction to a Situation Theoretical Framework

Version 2

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(As explained in the text, a Situation Theoretical Framework is indefinitely extendible.)

Manuel Bremer

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Preface

This essay outlines a *basic* Situation Theoretical Framework in the tradition of Situation Theory and Situation Semantics. It may serve as an *introduction* to the basic and some paradigmatic analyses in Situation Theory.

After some general methodological reflection on the attitude with which to use an ontology-based framework of analysis in §1, §2 presents the notation and basic concepts employed in the framework, the basic ontological categories of which are presented in §3. The framework revises and streamlines variations of Situation Theory Frameworks presented so far, both in conceptual as well as in ontological matters.

§4 and §5 outline the basic analyses of *information flow* and *meaning* as paradigms of Situation Theory (respectively Situation Semantics), which justify developing Situation Theory (including its formal and conceptual framework) further on. §4 also concerns the role Situation Theory can have for Cognitive Science with respect to information extraction by cognitive agents or information processors. §5 also relates Situation Semantics to current truth-conditional semantics.

§6 collects basic logical principles of information units (*infons*) and the framework in general. Infons come with an infon logic, and some closure principles are assumed. Some key elements and open issues are discussed.

Using the resources of §§4 – 6 a basic analysis of (propositional) attitudes and action is developed in §7. This paragraph exemplifies both the dominantly externalist approach of Situation Theory, as well as meta-representational infons in attitude reports. Action analysis extends §4 on information flow and extraction.

The expressive power of the framework allows for circularity and self-reference, which benefits the expressive power of analyses, but, then, variants of the semantic paradoxes have to be considered, in §8. Situation Theory cannot avoid the debate around paraconsistency and restrictions in infon logic.

Finally, in §9, one may ask how the framework may serve in computational analyses. The static character of analyses in formal ontology seems to stand in contrast to procedural computational models.

The first Appendix takes up the remarks of §1 how one may reduce or forsake the controversial ontological posits of Situation Theory without renouncing the use of a Situation Theoretical Framework. A set theoretical and a nominalist reduction are hinted at.

The second Appendix offers a preliminary evaluation of a Situation Theoretical Framework. Situation Theory came up as a promising 'newest thing' in the 1980s, in the 2020s it is – at best – recognized as one approach among others (besides older approach like Categorial Grammar, which it has not replaced, and recent trends like Cognitive Linguistics, which oppose its externalism). Do we need analyses of its format (e.g. in comparison to other approaches in semantics and Cognitive Science)?

The framework is also basic in the sense that highly technical background theories and proofs are avoided. Not all issues raised (say, for infon logic) are resolved. A graduate level knowledge of meta-logic and formal ontology should suffice for understanding. Each paragraph refers at the end to some further sources.

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§1 Basic Methodological Reflections

Situation Theory (ST) is a theory of *objective content* of representations like sentences (a.k.a. *external content*) and objective *information* present in situations and flowing from situation to situation, at least for systems capable of extracting information. ST does not focus on the vehicles of thought and language, but on their content, although, of course, representations are crucial when talking about those cognitive systems capable of propositional attitudes. The focus on information present in reality and the informational (i.e. external) content of representations calls for an ontological instead of a linguistic foundation of ST. Units of informational content and information flow come first, meaning and intentionality subsume under the primary model.

ST comes with an ontological framework that extends the ontologies that accompany classical logic – even classical modal logics – in their model theory or other semantics. A reflection on the attitude of grounding analyses in such an ontological framework may, therefore, be the starting point of working with ST. Some of ST's posits may be deemed outrageous (like *possibilia*), other simply beyond comprehension (like variable objects). Could one benefit from analyses in ST, nonetheless?

A modelling framework can be taken with realistic, constructivist, instrumentalist or fictionalist attitude. The attitudes are ordered by being less committal:

(i) A realistic attitude has to assume that up to logical equivalence the rules and representations of the model are operative in the capacities analysed. The posits involved in the model have to be assumed as existing, like in scientific realism. A structural realism will focus on the rules and procedures, and will leave leverage whatever carriers support these. A realist explains the success of the model by *correspondence* to reality.

(ii) A constructivist attitude assumes that the rules and representations of the model *by* being constructed in their role are justifiable assumed (up to logical equivalence) to be involved. A constructivist leaves the list of categories and rules open-ended, because more complex phenomena may require further construction. A constructivist explains the success of the model by its detailed grip of the *processes* involved in the *phenomena*.

(iii) An instrumentalist attitude assumes that the rules and representations of the model are concerning explanations and predictions *empirically equivalent* to any final analyses, if such be available at all. The posits in the model have not to be assumed to be existing. Instrumentalism and structural realism agree on the character of the posits, but might disagree on the psychological reality of the rules and procedures, up to logical equivalence. An instrumentalist explains the success of the

model by its being consilient to the real structures, whatever they are.

(iv) A fictionalist attitude will accept the modelling framework as it stands, given its empirical adequacy. It *denies reality* to at least the posits of the model, if not the representational format involved. It agrees with instrumentalism on the usefulness of an empirical adequate model, and might even agree with structural realism that such a model captures some structures, which, however, have to be understood in a different manner to the framework at hand. A fictionalist explains the success of the model by some parts of it being able to be anchored to real structures, while the rest of the framework may be *mere scaffolding* justified by its empirical adequacy.

Philosophical analysis in the tradition of Analytic Philosophy going back to Logical Empiricism is compatible with all four attitudes, but closest to instrumentalism and structural realism, with fictionalism being a fallback position or a variant of instrumentalism. Logical Empiricists see adoption of a modelling framework at least in parts as leaving some options, disagreement about which will be a side issue in comparison to the real work of analysis. Adopting and developing a framework or formal language has an aspect of constructivism. They need not oppose ontological reduction pursued with the aim of rendering the posits of a framework more acceptable (like in a nominalist re-construction of a framework with abstract entities), but it is not in the foreground of their concern. Famously Carnap's *Principle of Tolerance* admits anyone to develop whatever framework if it turns out useful. ST analyses may fit this leniency very well.

Nonetheless, ontology is just one step away from metaphysics, abhorrent to Logical Empiricists, and better left to science. Thus, a two-step approach to formal ontological and logical modelling appears:

(i) in the first – major – step a framework is developed to provide the best possible (comprehensive, explanatory, predictively successful) analyses of the field in question, typically cognitive capacities (e.g. language use, inferring, belief acquisition and revision). The framework will use representational formats (logical forms) and posits (entity categories) promiscuously, if only they serve best in analyses. Even though one should expect many unresolved questions, and thereby an open structure of the framework to be extended.

(ii) In the second – maybe indefinitely postponed – step a framework will be refactored in its components. Like in software refactoring entity categories and types may be reduced or abandoned in favour of others. The procedures may be

rephrased with an eye to efficiency or feasibility (for a human mind, say).

In this vein *Situation Theory* (including *Situation Semantics*) has been developed as a comprehensive framework to analyse the flow of information (including meaning and knowledge). The framework introduces an ontology suitable to explanations in a perspicuous vocabulary (i.e. close to common concepts of what is involved in information flow, say regularities and items of information). Supposedly the whole framework above the basic items (here, at least, real situations) could be cast in some set theory – but what for?

Situation Theory takes up elements of analyses in terms of classical FOL, SOL, philosophical logics, and model theory. ST stems from the work of John Perry and Jon Barwise, and their collaborators and followers. It emphasizes referential/objective semantic content, partiality (of information), and situated contexts of language use. Perry and Barwise announced "bringing ontology back into semantics", against the long shadow of the anti-metaphysical spirit of Logical Empiricism. ST comes with an elaborated and many-sorted ontology centred around the concept of situations and their parts, as well as the ontological aspects of language used in situations. It was a new approach in the 1980s, but has not replaced the dominance of other frameworks (like classical *Model Theory*, or *Categorical Grammar*, cf. van Bentham & ter Meulen 1997), or stopped the turn to psychological theories (like 'Cognitive Linguistics') supposedly more adequate than logic-based, formal ontology frameworks (e.g. cf. Croft &

Cruse 2004). The origin and history of ST and their proper interpretation will not be a topic here. Renewing interest in applying ST to other topics than covered in §§4-8 motivates outlining this SF.

By "Situation Theoretical Framework" (SF) the notation, formal language, its logic, and its ontology is meant. "Situation Theory" (ST) means the overall theory introducing SF, its meta-theory, and the analyses delivered using SF.

The SF outlined here starts from work in the ST *tradition* to

(i) *develop* and *extend* a general framework in the ST tradition, and
(ii) be able to deploy this framework to deliver analyses following – at least in parts – the ST tradition.

It streamlines notation and ontology (forsaking some elements in the ontology and conceptual *repertoire* of earlier ST [cf.§§2 and 3]). The SF outlined, however, comes with a promiscuous ontology of *possibilia* and inconsistent entities (in *this* respect going even beyond original ST ontology), going back in parts to the traditions of 'structured facts'/'structured propositions' (say in early Russell, cf. Russell 1903), and versions of Noneism, from (Meinong 1904) to (Routley 1979) and (Priest 2005). Analyses with this SF, thus, can be identified with the first step mentioned above.

One may consider the posits – and, maybe, the representational format – of this framework *outrageous*, not to be taken realistically. Rightly so, but instrumentalism/fictionalism will be an option. Bringing an ontological *narrative* to semantics and epistemology need not disturb even a Logical Empiricist. Other work might concern itself with the second step of refactoring SF.

[See, however, the first Appendix for some hints at reductions of SF.]

ST more or the less neglects *syntax*. This hinders a proper treatment of (mental) representation, and computation. It shifts the focus on relations between *contents*, and the content 'out there' in reality, to be grasped and processed by (cognitive) agents.

The aim of ST is to develop and establish a comprehensive SF which is able to analyse semantics, pragmatics, knowledge and information flow *in terms of an ontology* of situations, infons and categories derivable from them. This ontological approach may well be worthwhile to pursue, at least as an alternative option to be compared and contrasted to representation centred approaches. Thus, the need for a regimented SF.

Given the central concept of 'information flow' issues of computability have to be taken up at some point in SF [cf. §9].

Foundational texts of ST are: (Barwise 1989), (Barwise & Perry 1983), (Devlin 1991).

The exposition of the basic parts of SF follows mostly these works, with some distinctions set out in the following sections. So, for instance, situations are never defined using epistemic concepts (like sets of infons made true by them), because as parts of reality they can outrun our epistemic resources. Focussing on their spatial and temporal relations decreases the reliance on locations and times. The decisive role of infons in SF follows Devlin and drops talk of "abstract situations" and "state of affairs", and so on. Others differences in notation and ontology will just show up in the development of SF, as the history of ST is not our main concern.

ST has also been non-standard in set theory – at times, at least – in comparison and contrast to classic set theories like ZFC (cf. the use of KP in Barwise & Perry 1983, and ZFA in Barwise & Etchemendy 1987). ZFA (Aczel 1987, Barwise & Etchemendy 1987: 34-58, Devlin 1993: 143-83) was another 'newest thing' in the 1980s. ZFA came into focus in the ST tradition when dealing with circularity in ST. A situation (or infon) involved in circularity or self-reference could be modelled by a *hyperset* (a non-well-founded set of ZFA). This move (e.g. in Barwise & Etchemendy 1987, cf. more general: Barwise & Moss 1997), however, abandons the very core assumptions that real situations are parts of spatio-temporal reality, and that infons are abstract entities *sui generis*.

We start here with these core elements of the original conception. The current SF, for this and other reasons, therefore,

conceptualizes sets – until further notice and paradoxes – in the standard manner of ZFC. Circularity has to be dealt with in some other way. Reflections on the expressive power of SF (including the danger of paradoxes due to self-referentiality and circularity [cf. §8]) may force extensions or modifications. One major difference in the current SF concerns the treatment of paradoxes that might come with the expressive power of SF: paraconsistency and even some form of dialetheism (cf. Priest 2006) are options for SF.

Another difference – seen here only on the sidelines, though – may be turning to a 3rd truth-value for indeterminate cases of vague expressions, which are ubiquitous in natural language. So that the intended SF might use 4 truth-values in all (True, False, Neither, Both)!

(Barwise & Perry 1985) rejects Meinongianism, but if ST understands itself as a realist *ontological* approach (starting from the main categories *Situations* and *Infons* [cf. §3 and §4]), then, infons are neither sentences nor another type of representation, but *sui generis* abstract entities containing *objects* as their constituents. Neither can (Barwise & Perry 1985) take *roles* and *variables* in infons [cf. §3, again] as *concepts* without moving from ontological realism to conceptualism or representationalism, both of which they want to leave behind. Concepts are representations, say in the *Language of Thought*. If one wants to place concepts where *possibilia* occur in infons, it becomes a *contingent* matter when this happens (e.g. because an object has gone out of existence), and thus quantifying-in may be feasible one moment, and not the next. One area requires representations of some sort (mental or linguistic): in indirect speech and attitude reports it will be unavoidable to include representations into infons, as indirect speech and attitude reports are even more fine grained than reference to *possibilia* [cf. §7], but in all other areas infons should contain the entities they are information of.

The SF here bites the bullet of a really promiscuous ontology. One has to see how convincing analyses in this framework turn out to be. Ontological leniency may foster succinct analyses. And *if* one finds the analyses [in §§4, 5, 7] fruitful or convincing, then one can turn to an endeavour to rid oneself of the promiscuous ontology [as in the Appendices].

§2 Basic Notation and Concepts

Notation and logical and ontological principles are typically introduced piecemeal in ST analyses. This section provides a first and incomplete overview to accustom to the framework. Some of the notation is shortly explained here, longer explanations will follow later (§§3-6). Notation and usage – even of the basic concepts like 'situation' – *varies* within the ST tradition (even within work by the same authors), so this SF presents some streamlined (i.e. consistent and reduced version).

Keeping in mind that SF contains on the one hand a formal language (used e.g. in ST analysis and talk *about* information) and on the other hand a notation *for* information (units), which are not linguistic, requires some sophistication, and requires explicit distinctions (e.g. between sentences and infons). Keeping this in mind, again, allows to use some notation on both sides of the distinction (e.g. using logical particles both in the formal *language* as well as *in* infons).

[Therefore, this paragraph on notation alludes sometimes to some substantial theory.]

The notation and formal framework should be employed when natural language expressions are cumbersome, ambiguous or not precise enough. In many contexts the proper precise (fully expanded) expressions of the framework, however, would be cluttered, because of fine distinctions which for many contexts are not relevant, so a liberal use of the notation, precise enough for anyone with some knowledge of formal ontology and, say FOL, formalizations, seems clear enough (a.k.a. 'informal rigour').

[There are some nitpicking parts, though.]

The framework in this format is a *many-sorted*, *higher-order language and logic*. Thus (by well-known meta-logical theorems), it cannot be recursively axiomatized and axioms/rules are to be added indefinitely. It allows for some circularity/self-reference, and paradoxes have to be dealt with or some form of paraconsistency has to be integrated.

The sorts of entities are the *categories* of SF. *Types* can be introduced as abstractions *in* a category. Categories define the framework. Types define theories expressed within it.

Standard logical symbols are employed:

$$\neg, \wedge, \vee, \supset, \forall, \exists, \in, \vdash, \models, \cup, \cap, \subseteq, \Box, \Diamond, \top, \bot$$

Connectives and quantifiers are *overloaded* (in the programmer's sense) by use in sentences and infons (i.e. in one use relating *linguistic* items, in one use parts of informational *content*). (This is one of the sophistications mentioned above. It simplifies notation most times avoiding a double for each particle, but the dual character has to be kept in mind. If the difference matters crucially, a symbol will be indexed [I] for infons. An infon contains *the function* expressed by the symbol.)

Additional symbols and constants:

$\rightarrow$ and $\longleftrightarrow$ in statements of (definitional) *rules* and in *principles* (i.e. one level up)

$\Rightarrow$ in constraints

$\Vdash$ truthmaking: situation *s* makes infon *i* true: $s \Vdash i$ (also used with sets of infons)

: type assignment: situation s_1 is of situation type S_2: $s_1 : S_2$

~ predicate negation in sentences: so, indeterminacy means: $\neg P(a) \wedge \neg{\sim}P(a)$

@ existence property (being *actual*), corresponding to the predicate constant "E!( )", also used as a subscript;

NON@ being *non-actual* (i.e. being *merely* possible)

CAUSE relation of causation between situations, a constant (there are a few more)

ACCESS ternary accessibility relation used for a Relevant Logic conditional

$\ast$ Routley Star

ι description indicator

® representation indicator: for entity *x* there may be rep resentations of it, which are relative to an agent: ®x.

If the agent has several representations of *x* they are enumerated: $®_1$x, $®_2$x ...

∀@, ∃@	quantifiers restricted to parts of reality (i.e. really existing entities)
α, γ , α_1, γ_1 ...	are schematic for sentences
δ, δ_1 ...	are schematic for terms (sub-sentential expressions)
φ, ϕ, φ_1, ϕ_1 ...	are schematic for infons
Γ, Γ_1 ...	are sets of infons
Σ, Σ_1 ...	are sets of sentences
Λ, Λ_1 ...	are sets of information (containing infons and constraints)
$\|\| \alpha \|\|$	the semantic value of a representation (in this case some sentence α), also
$\|\| \delta \|\|$	for sub-sentential expressions

Ordinary language predicates and names may occur in infons and sentences *ad libidum*. Relations begin with a capital letter, object identifiers with small letters. Proper names are kept capitalized. Blanks in terms are avoided (like with identifiers in programming languages). Thus: “BrotherOf”, “atticWindow”, “George”.

Infon representations in SF may contain *pictograms* or pictures to highlight that infons contain *entities* and in most cases not words – apart, of course, of infons about language. In case of general conditions in a situation one pictogram may suffice, e.g. s⊩<<>> being a situation where it rains, corresponding to “It rains”, where there is no entity *it* that does the raining.

Apart from their use in type abstracts, square brackets are used as corner quotes of expressions of SF. Expressions can also be quoted. Scare quotes refer to concepts.

The ontology is many-sorted; expressions are indexed by subscripts; in (rare) cases where the difference between an indefinite reference to an entity of a category and reference by a (not further specified) constant is relevant the subscript ends with “c”, and variables are starred by “*”. An expression bound by a quantifier or abstract is used as a variable (e.g. “s” will be used indefinitely for some unspecified situation, but in “∃s(...s....)” it is used as a variable).

s, s_1, s_2, ... denote situations indefinitely;

s_{1c}, s_{2c}, ... are situation constants; s*, s^*_1 ... situation variables – and similar for other ontological categories [cf. §3 on the category of variables]. For better readability expressions without an index used in the main text are italicized (e.g. “given some situation *s*”, but “given some situation s_1”).

Situations can be related in time or space by preceding, coinciding or overlapping (spatially preceding means to be a spatial part): $\prec_t, =_t, \bigcirc_t$ $\prec_s, =_s, \bigcirc_s$

Situations can be parts of other situations or identified with them: $\prec$, =

Statements and infons with these relations are noted mostly in infix notation, i.e. [$s_1 \prec s_2$] instead of [<< $\prec$, s_1, s_2, T>>]

$a \prec s$ individual *a* is present in situation *s* (notation motivated by thinking of presence as being a constituent part of the situation); similar for the other categories; standing alone $[a \prec s]$ is used as *statement*, and as *referring to an object* in identity statements: $a_1 \prec s_1 = b_{23} \prec s_7$.

$\precsim$ proper part: $s_1 \prec s_2 \land s_1 \neq s_2$

$w_@$ reality (the unique total real situation): the actual world

$w, w_1, w_2 \ldots$ possible worlds (possible total situations), not being sets

$S, S_1, S_2, \ldots$ are situation types

$C, C_1, C_2, \ldots$. are constraints

$a, a_1, \ldots, b, b_1 \ldots$ are individual constants

$a^*, a^*_1, \ldots, b^*, b^*_1 \ldots$ are individual variables

P, P_1, P_2 ... properties; P^*, P^*_1, P^*_2 ... property variables

R, R_1, R_2 ... relations; R^*, R^*_1, R^*_2 ... relation variables

Properties are 1-ary relations, thus when general principles refer to 'relations' this includes properties. Some relations have relations as arguments, which can be quantified over in SF as Higher-Order Logic. Relations are denoted by *general terms*. Individuals are denoted by *singular terms*. If no confusion is likely, infons can be expressed by "that"-nominalizations, but they are not sentences/propositions.

Some relation constants express basic 'propositional attitudes': BELIEF, KNOW, WANT and speech acts like ASSERT ...

INFORMED relates information processors and infons *without* assuming a propositional attitude in the information processor.

$x^*, x^*_1, y^*, y^*_1 \ldots$ are generic variables (e.g. used in the statement of rules or principles generalizing over categories)

$f, f_l \ldots$ are anchors, which relate variables in infons to entities of their category in a situation; they resemble assignments under an interpretation *V* in Model Theory):

$f[\phi_1]$ is an anchored infon (relative to some situation *s*).

$l, l_1 \ldots$ are locations, which can stand in relations $<_s, =_s, \bigcirc_s$

s_l being *the location* of *s*

$t, t_1 \ldots$ are times, which can stand in relations $<_t, =_t, \bigcirc_t$

s_t being *the time* of *s*

Truth-values: T (True), F (False), N (Neither), B (Both True and False)

[N] means that the application of some relation to some objects is *semantic* indeterminate (i.e. [N] is not meant epistemically, cf. Bremer 2026), [B] applies to inconsistent statements (maybe dialetheias), in case one wants to have a paraconsistent SF.

$i, i_1, i_2 \ldots$ denote infons

$i^*, i^*_1, i^*_2 \ldots$ denote infon variables

Infons are noted within double corners:

<<Relation, Arguments, Truth-value>>

(for example: <<Rainy, Bonn, 30.05.2026, T>> if "Rainy" ascribes the weather condition to a place at a time). In case the argument places of a relation have no fixed order, they may be annotated by their *thematic roles*, e.g. <<Kiss, agent: Mary, patient: Jane, T>> (like 'decorated' arguments of functions in some programming languages).

Infons using T as constitutive truth-value are *positive* infons, those using F or N *negative* infons, those using B, if any, are both. Infons state that some relation between entities obtains or does not. If no confusion can arise one may drop [T] in the truth-value slot, because instantiation information with respect to some relation serves as *default*: using "<<R, a, b>>" for "<<R, a, b, T>>".

If infons in a set of infons supported by a situation or two situation types or conditions in a constraint share some variables (say [x*], [x^*_1]), they have to be assigned values *uniformly*, resembling a *unification* algorithm in program semantics.

cont(α) = φ the infon φ is the *content* of sentence α

Situation types are introduced by abstraction: [s | s $\Vdash$ <<Cat, George, T>>] is the type of situation which make the infon true that there is a cat named "George", $_{\text{George}}$. The infons used in the situation type are the *conditioning infons* of that type.

cond(S_3) = i_{45} the *conditioning infon* of situation type S_3 is i_{45}

Types for other categories can also be introduced by type abstraction.

Two important types of situations are: Events, States. For ease of exposition sometimes special *event* expression are used:

e, e_1, e_2, ... denote events indefinitely; e_{1c}, e_{2c}, ... are event constants; e*, e^*_1 ... event variables; to talk about *states* situation terms are almost always sufficient.

Constraints link situation types (maybe adding some further conditions Γ, e.g. of temporal order: $s_1 : S_1 <_t s_2 : S_2$, where Γ can be a singleton or empty):

$C = S_1 \wedge \Gamma \Rightarrow S_2$

Terms are introduced in developing analyses, but some conventions of usage might prevent verbal disputes from the start:

- "consequence" – is used in the usual sense, and *extended to infons*: infons made true have other infons being made true as consequences of them, [$\vDash$] for sentences and for infons often have to be different, though [cf. §6]: [$\vDash_{SOL}$] *vs.* [$\vDash_I$]
- "entailment" – is used for $\Box(\alpha_1 \supset \alpha_2)$ and $\vDash(\alpha_1 \supset \alpha_2)$ (equivalent in modal logics with Necessitation), and *extended to infons* (like 'consequence', similarly qualified), "entailment" is *not* used for a conditional in Relevant Logic.
- "fact" – an infon made true by a real situation obtains, corresponds to a fact, which is part of that real situation (i.e. is a *structured chunk of reality*).

• “information” – used in the sense of ‘informational content’, need not be veridical (i.e. false statements still have informational content)

• “interpretation” – assigns referents to *constant* expressions, like in model theory

• “object” – mostly used *generically* in the sense of ‘entity’ (i.e. including relations etc.), if the category is important “individual” is used for ‘ordinary objects’

• “parameter” – a variable object with a fixed *role* (e.g. speaker of an utterance); speaking of anchoring the variables always includes the parameters; examples of such parameters are: speaker*, audience*, time*, utterance* (in that situation). Some parameters have obvious transparent readings for some situation: now*, here*; parameters $\subseteq$ variables;

• “principle” – in developing the framework one need not from the start distinguish the theorems from axioms of a systematically regimented framework, but classify both as ‘principles’, different systematizations will be possible.

• “proposition” – mainly used in one sense: assertive content of an anchored specific declarative utterance that some specific infon obtains in some specific situation (also referred to as “propositional content” of that utterance, cf. §3); used as well for the content of statements of type assignment; usage of “proposition” in the sense “state of affairs” or “sentential content” replaced by “infon”.

• “set” – refers to a set in the sense of ZFC and the cumulative hierarchy

• “statement” – only used for declaratives: assertions *that* something is a fact (i.e. *combining* some content with assertive force, *this* claim being the content of statements)

• “variable object” – infons are not sentences, so variable-like looking notation in infons relates to variable *objects* for a category; a *sui generis* category used in generic infons for anchoring

• “iff” – short for “if and only if”

Some terms not used are replaced by SF terms and concepts:

• “abstract situation” - not used, relevant uses of it correspond to uses of “situation type”

• “state” and “event” - not used as basic categories, as situations have spatio-temporal extent, but introduced as important types of situations [cf. §3]: Events, States.

• “state of affairs” - not used, relevant uses of it correspond to “anchored infon”

Many terms introduced somewhere in the ST tradition are *not used* if their intended use can be captured by this reduced and reformed SF. These include, for instance:

• “conditional constraint” - all constraints are conditional

•“preclusion” - captured by “exclusion constraint”

and some more.

Abbreviations used in addition to “ST” and “SF”:

• abbreviations for the well-known classical logics: PC, FOL, SOL, also well-known extensions of them: S4, S5, etc.

• abbreviation for well-known non-classical logics: LP, R, RM_3 etc., otherwise explained by reference to the literature

• abbreviations for well-known set theories: ZF, ZFC, KP

ZFA ZF with the *Axiom of Regularity* replaced by the *Anti-Foundation Axiom* (a.k.a. AFA); ZFAU = ZFA with a set of urelements (similar: ZFCU ...)

§3 Basic Categories

The basic categories ground ST and provide the core for ST analyses with SF. Central topics can be introduced and be treated mostly by them. Nonetheless SF is indefinitely extendible by further categories and their principles. SF works with several categories of entities and allows to quantify all of them. The intended structure exhibits the form of a Higher-Order Logic. So, on the one hand striving for a complete list of principles is in vain as SF as Higher-Order Logic is not recursively axiomatizable. It is, as always, possible to transform the system within a FOL meta-theory, which loses then all the practicality and ease of use of SF, and certainly is not the intended format or interpretation.

More importantly, on the other hand, ST aspires to integrate ever more (philosophical) topics in analyses by SF, so that with new areas of analysis new principles are to be added. So, SF endorses the constructivist spirit of ‘cognitive carpentry’: to have an explicit and formal framework with principles (be they like axioms or derived from them as theorems), but be ever open to extend it (cf. Pollock 1995).

Adding ever more principles or even categories and extensions of notation runs the risk of making SF rather unwieldy, but poses the positive challenge to see and solve issues of coherence in a comprehensive ST and SF.

The central categories of SF are *situations* and *infons*, other central categories (like relations and individuals) are directly associated to them.

Real situations are parts of reality. s_1 is a real situation as a part of the actual world (reality): $s_1 \prec w_@$. Physical situations have spatio-temporal extent. So, what might be said referring to times and places can be said by talking of the spatial and temporal relations of situations. We can talk (and quantify) over locations and times if convenient, but we are talking then about abstractions over the spatial and temporal relations of situations.

Spatially a situation may be a spatial part of another situation, overlap that situation or coincide spatially with it:

$$s_1 <_s s_2$$

$$s_1 \bigcirc_s s_2$$

$$s_1 =_s s_2$$

Temporally a situation may precede another situation, overlap that situation or coincide temporally with it:

$$s_1 <_t s_2$$

$$s_1 \bigcirc_t s_2$$

$$s_1 =_t s_2$$

One can immediately define:

$$(\leq_t) \qquad [s_1 \leq_t s_2] \stackrel{\text{def}}{=} s_1 =_t s_2 \vee s_1 <_t s_2$$

$$(\leq_s) \qquad [s_1 \leq_s s_2] \stackrel{\text{def}}{=} s_1 =_s s_2 \vee s_1 <_s s_2$$

A situation s_2 with $s_2 <_t s_1 \wedge s_2 =_s s_1$, for instance, is a part of *the past of s_1*. Truth-conditions for tense and aspect refer to such relations between situations. General properties of the universe can be expressed this way. For instance, in a discrete universe without beginning every situation has an immediate predecessor situation:

$$\text{(DU)} \qquad (\forall s_1)(\exists s_2)(s_2 <_t s_1 \wedge \neg(\exists s_3)(s_2 <_t s_3 \wedge s_3 <_t s_1))$$

If the universe has to have a beginning some initial situation has to be postulated – etc.

Time spans and durations can be modelled by situation sequences between a beginning (situation) and an end (situation). A sequence of situations $s_1 \ldots s_n$ can be recursively defined as an impredicative set:

$$[\mathrm{SitSeq}(s_1, s_n)] \stackrel{\text{def}}{=} \{s \mid s_1 \leq_t s \wedge s \leq_t s_n \wedge (\forall s_2 \in \mathrm{SitSeq}(s_1, s_n))(s \leq_t s_2 \vee s_2 \leq_t s) \wedge (\neg\, s =_t s_1 \supset (\forall s_2 \in \mathrm{SitSeq})(\neg s_2 \leq_t s_1 \supset s_2 \in \mathrm{SitSeq}(s, s_n))) \wedge (\neg\, s =_t s_n \supset (\forall s_2 \in \mathrm{SitSeq})(\neg s \leq_t s_2 \supset s_2 \in \mathrm{SitSeq}(s_1, s)))\}$$

A situation *s* is element of a sequence between a start situation s_1 and end situation s_n iff this sequence is a connex, connected order in which *s* finds its place somewhere. There are situation functions:

$$\mathrm{StartOf}(\mathrm{SitSeq}(s_1, s_n)) = s_1$$

$$\mathrm{EndOf}(\mathrm{SitSeq}(s_1, s_n)) = s_n$$

Now further temporal concepts can be defined, for instance: the *lifespan* of an individual is a situation sequence such that the individual is a constituent of all its situations, but not of any situation before or after:

$$\text{Lifespan}(a) = x \equiv (x = \text{SitSeq}(s_1, s_n) \wedge (\forall s)(\neg\, s \in x \supset \neg\, a \prec s) \wedge (\forall s)(s \in x \supset a \prec s))$$

and so on.

Reality is the unique total real situation: the actual world $w_@$. Reality is not a set or a description, but all that there is. Given that real situations have temporal extent and the past taken as real, reality is all that there is *and was*. $w_@$ is a *world history*: the way reality has been so far. *Convergence* holds for real situations:

$$(\forall s_1, s_2)\, \exists s_3\, (s_1 \prec s_3 \wedge s_2 \prec s_3)$$

made true by $w_@$. For real situations analogous convergence principles hold for spatial parthood and temporal precedence. Space is united. Time (up to now*) is a linear order.

Situations that coincide either spatially or temporally differ in the other dimension or are identical. This is an ontological principle of *extensionality*:

$$(1)\ \vDash s_1 =_t s_2 \wedge\ s_1 =_s s_2 \supset\ s_1 = s_2$$

A situation is a part of another situation if and only if they temporally coincide and the situation is a spatial part of the second situation. As a principle:

$$(2) \vDash s_1 =_t s_2 \wedge\ s_1 <_s s_2 \equiv\ s_1 \prec s_2$$

Parthood grounds in situations as entities, it is not derived from relations between sets of infons they make true, this would make the concept ‘situation’ epistemic. If one defines situations by such sets and employs set theory (even without the Axiom of Foundation) one will derive that there is no total real situation (e.g. Barwise 1989: 191), which seems bizarre when real situations are taken to be parts of reality, which should be present as a totality.

As situations have a temporal dimension, and can be extended, no basic category of events is needed. Events can be introduced as a *type of situation*, namely those situations which have a proper temporal sub-situation (i.e. a situation at the same place, temporally overlapping, but not identical with the situation):

$$\text{Events} = [\ s \mid (\exists s_2)(\ s =_s s_2 \wedge\ \ s_2 \,\mathrm{O}_t\, s \wedge s \neq s_2]$$

Situations of this type have *duration*, which is what differentiates events from states. The temporal parts of an event need not be events, but might be states. An event is constituted minimally by a pair of states. Unlimited divisibility need not be assumed. States can be defined:

$$\text{States} = [\ s \mid (\forall s_2)(\ s =_s s_2 \supset\ s = s_2]$$

States have no temporal parts, so what coincides spatially with them has to be identical to them.

For most analyses the presence or absence of duration is not central, so ‘situation’ is the basic category. This sounds at times unusual with respect to events given common usage, e.g. a game may be described as “situation (of the game)”, but an action is typically described rather as “event (of doing...)”, could however be described as “situation (of doing...)”. Common usage uses “situation” rather for larger chunks of reality. States may also commonly be described as the “situation ... is in”, thus states as situations sounds less unusual. By the types Events and States common usage can be recaptured if needed, but ontological systematicity favours ‘situations’ as basic category and focus.

All real situations are possible situations. Merly possible situations could have been real, but are not. They belong to the vast domain of *possibilia* in SF. There are no impossible situations – this is what “impossible” means. Another question, however, is whether ST and SF should allow for inconsistent situations, as there are certainly inconsistent infons. Agents can extract inconsistent information from situations, at least by error if not by inconsistent regularities they exploit when extracting information. One might develop SF as a paraconsistent or even dialetheic framework, or one does not, depending which topics a ST account should cover. Agents and information processors with inconsistent information should be describable in SF.

As there are merely possible situations, there are *total* merely possible situations: possible worlds w_1, w_2 … Like $w_@$ they are possible world histories. They are not sets, but ways reality could have been. A possible world *w* is a *merely possible* world if it is non-actual, i.e. if it is not identical to the actual world:

$$\vDash \text{NON@}(w) \equiv \neg(w = w_@).$$

Similar for merely possible situations: $\vDash \text{NON@}(s) \equiv \neg(s \prec w_@)$.

Situations belong to situation types. Situation types are introduced by abstraction:

$$S_1 = [\ s \mid s \Vdash \langle\langle \text{Cat}, {}_{\text{George}}, \text{T}\rangle\rangle]$$

is the type of situation which make the infon true (i.e. in which it is the case) that there is a cat named “George”. If s: S_1 then in s there is a cat named “George”: ${}_{\text{George}}$.

Abstraction defines by infons a type of entities of some category: situation types of situations, relation types of relations, and so on. Types are neither sets nor properties, but abstract. Types serve the purpose in SF to *express rules* (like constraints) as relations between types.

[As *a* being of a type *T* defined by some conditioning infon using some predicate *P* might be converted to some complex infon << ... <<P, a, ...>> ...>>, rules with types might be expressed by some quantificational complex infon, thus, types being *reducible* in the developed infon logic of §6, but they allow for succinct expression of rules.]

Not all situation types are instantiated (e.g., some might be inconsistent by the combination of the infons they include). Situation types have closure conditions, as have sets of infons, whereas it is a category mistake to say that situations have closure conditions themselves. Real situations are parts of reality; one may say that *indirectly* they have some closure conditions by the types they are of or the infons they make true.

Trivially each situation s_1 defines its singleton situation type $S_{s1} = [s \mid s = s_1]$.

Situations involve *objects* standing in *relations* or having *properties*. These are basic categories as well. Infons contain items of these categories – and, in fact, of all other categories.

Infons are the units of information. Infons are the objective (external) content of representations like sentences or diagrams. They are not linguistic entities, but contain the *entities* they are about. Contents of utterance are built up of infons and related types like situation types, which make use of infons. Information flow between non-linguistic situations relates infons by constraints between the situation types. Infons can be units of information that is *not given* or *cannot* be extracted from reality, they need not be related to representations of cognitive agents to exist.

“Information” in ST is not veridical: a false sentence has *informational content*, a non-obtaining infon. Principles of Veridicality etc. apply at the level of constraints.

Infons are noted within double corners: <<Relation, Arguments, Truth-value>> (for example: <<Rainy, Bonn, 30.05.2026, T>> if “Rainy” ascribes the weather condition to a place at a time). In case the argument places of a relation have no fixed order, they may be annotated by their *thematic roles*, e.g. <<Kiss, agent: Mary, patient: Jane, T>>. The relation at the first slot of an infon builds the frame of the infon (by its arity and argument selection principles). This is the *main* relation, which always has to be present (the ‘framing’

relation, which gives unity to the infon like the framing general term, in the Fregean tradition, gives unity to a sentence, cf. Frege 1962). The infon may contain further relations, which then have to be arguments of the main relation. The last slot of an infon contains the truth-value being *used*. (Truth-values are a basic category.) The infon can contain further truth-values as arguments of some relation. The double corners indicate that infons are not tuples (i.e. sets), but *sui generis*. The sentence “Linda is female” has the content i_1 = <<Female, Linda, T>>, i.e. *cont*(“Linda is female”) = i_1. The relation *cont* allows to move from sentence types to infons. The move is transparent in case of eternal sentences. More important, however, is the identification of the infon which is the content of a sentence token used in making a statement in a situation of utterance, where anchoring variables occurs. A declarative utterance has to be *interpreted by anchoring* in the situation of utterance and *interpretation* of the constant expressions. This result in identifying the statement made, and the propositional content of that statement. A statement is *relative* to a (natural) language. Different sentences can be used in a situation *s* to makes the same statement: “I am tired” asserted by Fred, and “You are tired” asserted by Linda towards Fred in the same situation *s* make both the statement that Fred is tired in *s*. If s = The kitchen of Fred’s house at 12 o’clock on September 14th 2011, the eternal sentence “Fred is tired in the kitchen of Fred’s house at 12 o’clock on September 14th 2011” expresses what the statement says. The propositional content of that statement is: s⊩<<Tired, Fred>>. Propositions are the objective content *common* to many statements of different (natural) languages. Informational content is language independent.

Type assignments, e.g. that some individual a_2 is of the individual type O_5 [$a_2 : O_5$], can also be directly used in infons like: << $a_2 : O_5$, T>>. (Note that the type is not a framing relation.)

Infons, by being *sui generis* abstract, non-linguistic entities, are *unique*: the *identity of an infon* is defined by (i) its constituents, in (ii) their structural position. Identity issue will, thus, be passed down to the identity conditions of the constituents. Two *descriptions* of an infon may look different as different names of the constituents are used. These have to be co-referential then. The names, again, are not constituents of the infons – apart from infons with meta-linguistic content.

Generic infons are infons which contain variables:

<<Dog, a*, Cologne, January 30^{th} 2008, T>>

this being the generic infon of a dog being around in Cologne on January, 30^{th}, 2008. Also

[s* | s* ⊩ <<Running, a*, T>>

is the (generic) type of situation where some individual is running. Most situation types will be generic. In fact, most infons are generic. This is because relations and their expressions in natural languages are *polymorphic* (allowing for different sets of arguments), e.g.

(1a) Fred bought the record.

(1b) Fred bought the record three days ago.

(1c) Fred bought the record three days ago in Cologne.

(1d) Fred bought the record three days ago in Cologne from Underdog Record Store.

(1d) Fred bought the record three days ago in Cologne from Underdog Record Store for 30 €.

On many occasions not all arguments (thematic roles of the relation *Buy*) are important, but for any of statement of (1) being *true* some entity has to occupy that role. We can learn some *partial* information from any of (1), i.e. from the infons they express. Arguments and parameters can be *suppressed* in an infon. Analysis in SF will display only those variables in an infon which are relevant for the analytic purpose at hand. This applies to variables in an infon and to roles constitutionally present in situations of utterance (e.g. speaker* etc.).

Infons are not sentences but a category *sui generis*: the objective contents of representations like sentences or diagrams, and information units of information relative to a situation. As such units they do not consist of symbols, but contain the entities they concern (i.e. relate by their framing relation). Therefore, the variables in infons are *not* linguistic signs either. We call them “variables”, but they are variable *objects* of some category. Variables are *indefinite entities* of the category they are variables of. They are *sui generis* entities as well. With a generic infon <<P, a*>> we have no specific informational content, but the generic content that some individual which will be anchored to [a*] in a situation *s* has the property *P* in case *s* makes this anchored infon true. [a*] being a variable object of the category of individuals can only be anchored to individuals and occur at argument places for individuals. <<P, a*>> is not the non-generic infon <<∃, a*, <<P, a*>>>> which carries the information that *there is* some *P* [on quantifiers in infons cf. §6]. Talking or being informed *about* variable objects themselves poses some issues of expressibility, because the infons in which they occur are not about *them*, but the objects possibly anchored to them [cf. using CATEGORYOF below].[1]

As infons contain the entities they concern, and there are not just obtaining infons, but, for instance, infons which are the contents of sentences describing merely possible situations, there are infons containing the entities they concern *without* these entities *being related* in any fact (in some real situation). This poses on the one hand no problem – in distinction to Russell's problem with structured 'propositions' as contents of false sentences – but on the other hand entails that entities not existing in reality (like Pegasus and Count Dracula) *are* contained in infons like any ordinary existing entity. SF comes

[1] Such extravagant and not easy to conceive of posits come with the ontological approach of ST. In a reduction of SF, say, to some set theory, some sets by postulate will occupy this role, correspondingly for some nominalist linguistic reduction – but we do not care about reduction, yet, cf. §1. In the end, one has to weigh the fecundity of an ST analysis of informational content and information flow in all its form against its overgrowing ontology.

with a domain of such *possibilia*. They can be quantified over, but existence [@] does not apply to them.

Quantifiers in SF behave like in some Free Logics (cf. Lambert 1991). Quantifiers in SF are *not* restricted to existing entities: [∃a ...a...] means that there is some possible individual such that ..., [∃a (@a ∧ ...a...] means that there is an individual existing in reality such that ... So, semantically, one has to distinguish between (i) the general or *outer domain* of all *possibilia*, [∀] and [∃] range over this domain, and (ii) the restricted or *inner domain* of *existents*, [∀@] and [∃@] range over this domain. Besides this distinction between general and restricted quantifiers there are quantifiers *restricted* to the parts of a situation, used when situations make quantificational claims true [cf. §6]. The inner domain comprehends the parts of $w_@$. Descriptions like "the *P*" [ιP] could be introduced over the outer domain or over the inner domain (like in *Minimal Free Description Theory*, Lambert 2003). Given the SF promiscuous approach in analyzing *de dicto* attitudes, SF employs the former approach. In that approach two descriptions referring to mere *possibilia* (e.g. "The Headless Horseman" and "The Lord of the Rings") refer to different *possibilia*.[2]

In case of a generic infon i_1 with a suppressed parameter (suppressed argument of the framing relation of i_1) there will be an *extended* infon i_2 with that parameter made explicit or the

[2] In Negative Free Logic both just fail to refer, refer to nothing, which Negative Free Logic then deals with.

thematic role being occupied by some entity, and there will be two situations s_1, s_2:

$$s_1 \Vdash i_1 \text{ and } s_2 \Vdash i_2 \text{ and } s_1 \prec s_2.$$

If infon ϕ contains some variables (i.e. is a generic, not a complete infon) then the type

$$S = [s^* \mid s^* \Vdash \phi]$$

is a generic situation type and ϕ the *conditioning infon* of that type S: $cond(S) = \phi$. ϕ has to be anchored to the situation of usage to yield a complete infon.

If φ is a generic infon and f an anchor for some variable [x*] in φ, $f[\varphi]$ denotes the infon resulting from replacing variable [x*] in the many-sorted dom(f) by f(x*) of the proper category. If f is an anchor defined on all variables of ϕ, we can have

$$s \Vdash f[\phi]$$

the situation *s* makes true ϕ as anchored by this specific anchor *f*.

In a situation of utterance *s* parameters in infons include the utterance*, the speaker*, the audience*, the time*, the location*. Parameters which play no role in an utterance (by corresponding indexicals) and its content infon need not be anchored.

Example:

Suppose Fred asserts at 5 p.m. in the kitchen, towards Linda:

α = "I left the bread here for you 10 Minutes ago."

Then, taking about two contextually known constant object (the bread, the kitchen):

(i) the indexical "I" corresponds to the parameter speaker* and is anchored to Fred,

(ii) the indexical "here" corresponds to the parameter location* and is anchored to the kitchen,

(iii) the indexical "you" corresponds to the parameter audience* and is anchored to Linda,

(iv) the indexical "10 Minute ago" contains a reference ("... ago") to the parameter time* and is anchored to 4.50 p.m. using some temporal reasoning.

So, the token sentence α uttered by Fred has the infon φ as *generic* content, $\varphi = cont(\alpha)$:

φ = <<LeaveFor, agent: speaker*, object: bread_c, recipient: audience*, location*, time*-10 minutes, T>>

This is *anchored* to:

$f[\varphi]$ = <<LeaveFor, agent: Fred, object: bread_c, recipient: Linda, kitchen_c, 4.50 p.m., T>>

Fred asserts the *proposition*:

$$s \Vdash f[\varphi]$$

which says: 'It is a *fact* (in this situation *s*) that Fred left the bread for Linda in the kitchen at 4.50 p.m.'

If now Linda has reasonable doubt about that (e.g. no bread to be seen at the time of utterance), Fred needs to provide some reasons (some evidence, maybe) that the proposition is true.

Complete anchors assign a referent of the proper category to all variables in an infon, otherwise the infon stays generic.

Anchors supplement *interpretations*, which assign referents to the constant expressions composing a sentence (external content of the constants). Interpretation can best be understood as transparent: ||Fred|| = $_{\text{Fred}}$. ||Rainy|| = *Rainy* =  – the depiction of a property or relation (the referent of a general term) being more difficult than in cases of individuals. Interpretations of constant expressions do not differ relevantly from interpretations in model theory – the innovations of ST are minor here (like taking relations for real, instead of modelling them by sets).

$$s_{1c} \Vdash f_{10}[\phi_{23}]$$

is the *proposition* that in a specific situation some specific infon anchored by a specific anchor obtains. Claims like this are the *propositional content* of declarative utterances (statements) in a situation. Propositions *assert* that some infon corresponds to a fact. Propositions – in SF, in contrast to typically uses of "proposition" as contents – are the *combination* of content (modelled by infons) and assertoric force. SF follows Frege's conception: a 'Behauptung' is a *combination* of

assertoric force (expressed by the *assertion sign*: |), with a sense, a 'Gedanke' (expressed in a sentence), so that given a sentence α we consider its content (–α, using the content operator, expressed by the *content sign*: –), which is then asserted, given in total: ⊢α (cf. Frege 1962: 31-35).

This assertion (and thus this proposition) may be correct or incorrect. Justifications aim as establishing that the proposition is justified, and thus may – absent further justified doubt – be accepted, which again means that one accepts some fact (cf. Lehrer 1990). The assertion/proposition made by the utterance can be accepted as true. The truth-value *of* the proposition is linked, but, of course, not identical to the truth-value used *in* the related infon.

Propositions, thus, are the *primary* truth-bearers, *secondary* the statements they are the contents of are truth-bearers, *tertiary* one can take the (eternal) sentences which are asserted in statements as truth-bearers.

With the example sentence and situation *s* given above:

$$s \Vdash \langle\langle \text{Tired, Fred} \rangle\rangle$$

may be a *true* proposition, the content of the *true* statement:

$$s \vDash \text{"Fred is tired"}$$

which allows us to say about the eternal sentence:

> "Fred is tired in the kitchen of Fred's house at 12 o'clock on September 14$^{\text{th}}$ 2011" is *true*.

The proposition being also the content of the true statement:

$s \vDash$ “Fred ist müde”

and so on.

Infons using truth-values T are *positive* infons, those using F or N are *negative* infons. If one allows for infons using truth-value B these are positive and negative, as to be expected.

If an infon is *supported* by a *real* situation the infon *corresponds to a fact*. The sentence which the infon is the content of is *made true* by the real situation. The infon supported by a real situation *obtains*:

situation *s* supports the infon *i* true: $s \Vdash i$

An obtaining infon *corresponds* to a fact, but *is not identical to a fact*, because facts are parts of reality and infons contain non-factual elements like truth-values. (Remember: Truth-values are another basic category.) Facts are real parts of real situations, infons are abstract entities *sui generis* in SF. [Infons are not sentences, but SF extends “made true” to infons as information units.]

Situations are *truth-makers* in ST. The semantic value $\| \alpha \|$ of a true (eternal) sentence α is a fact. Indirectly facts as parts of real situations are the *truth-makers* of sentences (i.e. eternal, referentially anchored, sentences).

Propositions are *absolutely* true or false: either $s_{1c} \Vdash f_{10}[\phi_{23}]$ or not, in contrast to some situation making an infon true, and some other does not. A true proposition is true in all real

situations. The same holds for classificatory propositions saying that some individual is of some type: $s_{1c} \Vdash a_{34} : H_{567}$.

Situations are truth-makers. ST endorses *correspondence* at the core of one’s theory of truth. Statements made in a situation (their objective content being an anchored infon) are true by corresponding to a fact (part of the situation which is their truth-maker). This can also indirectly be said about the (eternal) sentences expressing this content.

As assertions as speech acts involve a (minimal) responsibility to have some justification for them justification and coherence may be added as aspect of a complete theory of truth.

Given that some infons are the content of sentences, one can extend truth-making to sentences (either eternal sentences or sentences with their indexical elements and variables assigned values under a proper assignment under an interpretation mirroring the anchor of the infon [in the manner of Lewis’ General Semantics, Lewis 1972]).

So, for eternal sentences:

$$(\vDash 1) \qquad s \vDash \alpha \longleftrightarrow cont(\alpha) = \varphi \text{ and } s \Vdash \varphi$$

For non-eternal sentences:

$$(\vDash 2) \qquad s \vDash \alpha_V \longleftrightarrow f\,[cont(\alpha)] = \varphi \text{ and } s \Vdash \varphi$$

A non-eternal sentence true at *s* under some assignment under interpretation *V* has as objective content some anchored infon, which is supported by *s*.

A situation does not make a sentence true if the sentence has not an objective content made true by that situation. A statement made in *inappropriate circumstances* (an inappropriate situation of utterance) has objective content, but the *described* situation making this content true is no *real* situation, so the statement is not true.

Note the difference in notation; this way SF can include statements to the effect that some world makes some (set of) sentences true. (But, again, these are not sets, especially $w_@$.)

If

$$s_1 \Vdash \varphi_1$$

and

$$\neg (s_1 \prec s_2) \land \neg (s_2 \prec s_1)$$

then, although the fact corresponding to φ_1 is not part of s_2, it is still a fact; truth-making is relative to a situation, but facts (just) are.

As said above: type assignments can also be propositional contents (especially in attitudes of classification). They assert that the infon yielded by conversion obtains.

An infon made true containing the truth-values T or B corresponds to a *positive* fact (i.e. a structured part of reality, this part being part of the real situation which makes the infon true).

Situations and infons being basic categories the relation $[s \Vdash \varphi]$ for some single basic (not logically complex) infon φ is *basic* as well: If φ claims some entities *x*... to stand in relation *R* and

is made true by real situation *s* then reality is such that *R(x...)* is a fact. (Remember: situations are not set-like.) Given this, truth-making conditions for complex infons and sets of infons can be defined recursively [cf. §6].

Infons can occur in infons directly and indirectly (e.g. in case support by a situation is part of an infon, or in case of infons about attitudes and their content).

If an infon contains somewhere nested a generic infon, the infon is generic itself.

Example: one hears the bell, because someone not specified has ringed:

$$i = \langle\langle \text{CAUSE}, s_1, s_2, T \rangle\rangle$$

$$w_@ \Vdash i$$

$$i_2 = \langle\langle \text{Sound}, 🔔, T \rangle\rangle$$

$$i_1 = \langle\langle \text{Ring}, a^*, T \rangle\rangle$$

$$s_1 \Vdash i_1$$

$$s_2 \Vdash i_2$$

$$s_1 <_t s_2$$

To be anchored all variables within a nested infon somewhere in an infon have to be anchored. Similar with nested situation types. Generic infons with only some variables anchored still carry information: partial information. Having or extracting partial information can be as useful as complete information, which agents seldom possess. Especially such generic types may be arguments of attitude relations, because these can be generic in real (mental) life, e.g.

$\Gamma = \{\langle\langle \text{Burglar}, a^*, T\rangle\rangle, \langle\langle \text{In},$  $_{\text{FredsHouse}}, a^*, T\rangle\rangle\}$

$s \Vdash \langle\langle \text{Fear},$ $_{\text{Fred}}, \Gamma, T\rangle\rangle$

Fred in *s* is afraid of some unspecified burglar being in his house.

A logical or semantic truth α is valid in the framework ($\vDash\alpha$) and the corresponding infon is made true by all situations – where else to place them? As a principle:

$$\vDash\alpha \rightarrow (\forall s)\ s\Vdash\varphi \qquad \text{where } cont(\alpha) = \varphi$$

and

$$\vDash\alpha \rightarrow (\forall s)\ s\vDash\alpha$$

Indirectly we classify such infons as ‘analytic’. Logical and semantical truths are sentences. Every situation makes these sentences true.

SF includes a logical system for sentences (supposedly incorporating FOL, SOL and principles of alethic, epistemic, temporal modal logics), and SF includes the principles of a logic of information units, which presumably differ in parts from the first, but are the new ingredient coming with ST.

Although situations are partial, this provides no reason why logical and semantical truth should not hold in them, as these are not related to situation specific content. The upshot of this

is that the information present in *any* situation is *closed* under logical and semantic principles [cf. §6].

To each specific situation *s* corresponds a set of infons $\Gamma_s = \{\varphi \mid s \Vdash \varphi\}$. This is the *informational content* of *s*, which is relative to the framework SF employed, because infons are relative to the resources of a framework whereas situations as parts of reality may not be exhaustively characterized by our resources. Infons are not sentences, but the SF ontology determines which infons there are. Relative to an ontological richer framework SF^+, thus, a situation will have more informational content. For each situation s_1 there is a situation type $S_{\Gamma s1} = [s \mid s \Vdash \Gamma_{s1}]$ of those situations *informationally equivalent* to it. The framework employed – especially if lacking resources on spatio-temporal relations – will not be able to distinguish situations of this type. Making a distinction between frameworks to deal with reality and reality, however, SF does *not* endorse any principle defining identity of situations in term of infons made true:

$$\nvDash s_1 = s_2 \equiv (\forall i)(s_1 \Vdash i \equiv s_2 \Vdash i)$$

right-side to left-side being invalid.

We might distinguish agents and systems also by the ontological framework *they* are working with. The information they can extract from a situation will depend on their framework, and the constraints expressible in that framework to which the agent or system is attuned or which the agent knows [cf. §4, and §5 on ‘conceptual schemes’].

As to each specific situation *s* corresponds a set of infons $\Gamma_s = \{ \varphi \mid s \Vdash \varphi\}$, the *informational content* of *s*, for $w_@$ this set is $\Gamma_{w@} = \{ \varphi \mid w_@ \Vdash \varphi\}$, which is the *set of all obtaining infons*, thus the set $\sum_{w@} = \{\alpha \mid cont(\alpha) \in \Gamma_{w@}\}$ is the *set of all truths*. [Note that this set contains only eternal sentences, their content can be anchored infons for non-eternal sentences used in that situation *s*.]

$\sum_{w@}$ calls for some non-well-founded set theory (like ZFA or some paraconsistent set theory with a universal set, like Routley's *Ultralogic*, cf. Routley 1979), or gains an 'incomplete universe' by *Cantor's Theorem* (cf. Grim 1991).

Given $\sum_{w@}$ the set $\{ x \mid x = \| \alpha \| \wedge \alpha \in \Sigma_{w@}\}$ is the *set of all facts*, which again contains all constituents of $w_@$. Thus, SF endorses the *Tractarian* thesis "The world is all that is the case".

An infon using the truth-values F or N claims an *absence*, which need not be understood as (1st order) negative fact, but exactly as an absence: the situation *s* making <<Hungry, 🕴 $_{\text{George}}$, F>> true is a situation where one cannot find George being hungry. The totality of positive infons Γ which can be established relative to *s* does not entail the infon <<Hungry, 🕴 $_{\text{George}}$, T>>. This exhaustiveness of Γ without the infon in question can be understood as a 2nd order fact. So infons using the truth-values F or N if made true can be understood as corresponding to negative facts, which again might be understood as 1st order negative facts – better understood as absences – or as 2nd order negative facts (relative to a totality Γ of infons covering the situation). *Totality claims* (e.g. the

claim that Γ is exhaustive with respect to the positive infons made true by a situation) entail a set of negative facts relative to this situation. Totality claims have to be added *explicitly*, because by default situations are partial and extendable. This entails the principle:

If $s_1 \prec s_2$ then $\Gamma_1 \subseteq \Gamma_2$ (for positive infons made true),

and $\Gamma_{2'} \subseteq \Gamma_{1'}$ (for negative infons made true).

Typically, totality of relevant positive information is *not* claimed, and therefore situations are *partial in their truth-making*, the set of infons made true by a situation is not negation-complete (i.e. containing either <<R, x..., T>> or <<R, x..., F>>).

Some infons using the truth-value B might be thought to relate, if made true, to a positive and a negative fact at the same time, which seems hardly comprehensible; even semantic antinomies when classified as B relate, in fact, to two positive facts (e.g. one evaluation of the Liar as true, one as the Liar being false), which contradict each other, but can coexist in a paraconsistent setting.

For an entity *x* there is the totality of positive infons Γ_x in which *x* occurs, and Λ_x the totality of information concerning *x*, and the set $\Gamma_{x,T} = \{\varphi \mid \varphi \in \Gamma_x \wedge (\exists s)(s \Vdash \varphi)\}$ of positive infons dealing with *x* made *true* by some situation: the totality of truth (*the* truth) about *x*. Such sets may be referred to in relative totality claims (i.e. that some situation contains the whole truth about something, from which can be inferred that only negative infons can be added). The situations mentioned in the definition of $\Gamma_{x,T}$ are parts of the world in which the information explored flows (*transworld* totalities $\Gamma_{x,T}$ make no sense – but $\Gamma_{x,T}$ may contain modal information about *x*).

SF uses set of infons (in condition sets in constraints or the informational content set of a situation), so *sets* are a basic category. Until further notice sets are conceptualized here according to ZFC, sets are well-founded, infons and types are not. Since SF takes real situations as spatio-temporal, and infons, and types as *sui generis* abstract entities, all of them are *not* sets. Work in the ST tradition, which turned to ZFA, gave up on the ontological status of at least one of them. This will not be done here to stress what is special about the approach of ST.

Individuals and properties as well as relations are constituents of situations, and uniformities across (sequences of) situations. [For illustration s few common ontological concepts may be phrased in SF terminology here.]

Sortal predicates express properties which constitute identity conditions of individuals. A predicate is of type Sortal iff objects that exemplify it, exemplify it in all cases (i.e. all situations) where they are present (i.e. are constituents):

$$\mathrm{Sortal} = [P \mid (\forall a)(P(a) \supset (\forall s)(a \prec s \supset P(a)))]$$

Correspondingly, Individual is a type of objects which whenever present exemplify a sortal:

$$\mathrm{Individual} = [a \mid (\exists P)(P : \mathrm{Sortal} \wedge (\forall s)(a \prec s \supset P(a)))]$$

Talking this way of ‘presence’ in situations *in general* includes also merely possible existence in merely possible situations. Otherwise only existing individuals had identity conditions. If an individual really exists, it necessarily exemplifies its sortal:

$$\text{(NI)} \qquad (\forall a)(a : \mathrm{Individual} \supset$$
$$\Box(@(a) \supset (\exists P)(P : \mathrm{Sortal} \wedge P(a))))$$

Sortal predicate exemplification can imply exemplification of other non-sortal predicates. One can define in general necessary (*essential*) properties (covering sortals and non-sortals): a property is a necessary (essential) property of an entity iff the existence of that entity is equivalent to exemplification of that property:

$$[\mathrm{Essential}(P,x)] \stackrel{\text{def}}{=} \Box(@(x) \equiv P(x))$$

Properties need not be assumed as abstract, but might be understood as ‘abstract’ only in the sense of existing where their property bearers are (like tropes), being thus dependent (or ‘unsaturated’ in Fregean terms). A property is real if there is a real entity (of whatever category) which exemplifies it:

$$\text{(Real Property)} \quad @(P) \equiv (\exists @x)P(x)$$

and so on.

All entities (of any category) can be quantified over – including the *possibilia*. Types can be introduced – if need be – by type abstraction, and used in type assignment statements. Types are not properties: properties occur in (real) situations, types are abstract entities.

All entity types can occur in infons (including situations, possible worlds and infons themselves). As infons, situations, and situation types can be quantified over supposedly there is enough circularity for self-reference, and thus for paradoxes [cf. §8]. Either SF has to put in some strong restrictions (on circularity or on an object-/meta-language distinction) or turn to be a paraconsistent framework. Given the promiscuous ontology infons can contain even inconsistent individuals like *TheRoundSquare* or inconsistent relations like *RoundAndSquare*, and so on.

Each entity belongs to some category, and these can be expressed as well by category predicate constants (SITUATION, PROPERTY, INFON etc.) The CATEGORYOF property and its predicate allow to express (or test in a condition) the category of an entity – like "typeOf" in some programming languages. This is more abstract than saying that some *x* is of some type *H* [x : H], because objects of the same category can be grouped in different types.

Apart from variables (i.e. variable objects) each entity belongs to exactly one category. For a variable we must have two infons, on the one hand

<<CATEGORYOF, P*, PROPERTY>>

because the variable [P*] can only be anchored to properties. This infon is *generic* with the tautological content that some property if anchored to the variable is a property.

We additionally must have the *non-generic* infon

<<CATEGORYOF, P*, VARIABLEOBJECT>>

which says *of* the variable object itself (i.e. not of an entity it will be anchored to) that it is a variable object, since otherwise we could not have the information – nor could express in a sentence – that a variable object is a variable object. The *sui generis* character of variable objects here shows in that CATEGORYOF can be applied transparently (for non-variable categories and for variables in the first infon) and opaquely to variable objects. This is one more postulate coming with the presence of variable objects – supposedly the most controversial posit of SF, eclipsing even *possibilia*.

Truth-values are a basic category as well. Their function in infons could easily be taken over by other objects (like numbers). Still the properties of *Obtaining* and *BeingTrue* could be treated as in ST/SF. Fregean 'The True' and 'The False' play no important role once situations and facts serve as referents.

The expression for truth-values, additionally, can also be used as binary operators to talk about the truth-values of statements and (indirectly) of sentences.

Weak [¬] and strong [~] negation have different impact on these truth-values in the 3-valued case: [¬] applied to an indeterminate vague sentence (truth value: N) results in truth-value T, since what the sentence says *is not the case*, but the *contrasting* property exemplification need not be the case as well for a vague property, so: ~N = N, etc. These and related issues are not especially relevant for SF, and whatever analyses seem best can simply be integrated into ST and SF (cf. Bremer 2026).

Ontological concepts and principles vary more or the less widely in the ST tradition (see for instance the applications and elaborations of ST in Cooper et al. 1990, O`Rourke & Washington 2007), the selection here attempts a streamlined basic version.

§4 Basic Analysis of Information Flow

If information is said to flow there has to be a system within which it flows. This system has to consist of parts which are separated one way or the other, otherwise there would be no need for information to flow from one part to the other. A system consisting of parts which are separated although constituting a unified whole can be called a "distributed system".

Information flow depends on relationships in a distributed system (e.g. a telephone connection). How the system is carved up is part of the model of the information flow to be explained. What might be a part in one situation/model (e.g. the telephone machine) might be a distributed system of its own in another situation/model. The parts of a distributed system are related to each other by the system as a whole. Regularities ensure the uniform behaviour of the system. One can see, for instance, a flashlight as a distributed system in which the parts are connected by being parts of the same system. Information flow depends on non-accidental connections (like between a switch and a light bulb lightening). Information flow depends on a *reliable* process. In the example: you use knowledge of such reliable processes reasoning from the information that the light is on to the information that the switch has been pressed.

That does not mean that information flow should be analysed using mainly the concept of causality, because:

(i) the direction of information flow is not necessarily aligned with the direction of causation (you can derive information about the cause from the effect),

(ii) every state participates in causal connections, but not all participate in informational dependencies,

(iii) in case of loose connections between parts of a system a *singular* causal connection might be not sufficient for information flow (as based on regularities), on the other hand

(iv) statistical regularities or those that can be exploited *often enough* can ground information extraction.

A causal connection, thus, is neither necessary for information flow (arriving at information from the effect to its cause) nor sufficient (a lose, probable causal connection between two events might not be reliable enough to get information about the second event from information about the first).

A lot of things are said to *carry* information: The rifle shot carried the information that the king was dead to the whole city. The e-mail message bore the information that Harry would be late for dinner. A common denominator is that in all cases some individual having some property matters: a_1´s being P_1 carries the information that a_2 is P_2 (for instance the light being on carries the information that the switch is pressed).

We can exploit this observation for a basic idea how to describe distributed systems: parts of a distributed systems are particulars with properties; they are of some type. This can be expressed by infons or situation types. Situation types are connected by *constraints*.

Constraints link situation types (maybe adding some further conditions Γ, e.g. of temporal order: $s_1 : S_1 <_t s_2 : S_2$, while the conditions set Γ can be a singleton or empty):

$$C = S_1 \wedge \Gamma \Rightarrow S_2.$$

or

$$C = s^*_1 : S_1 \wedge \Gamma \Rightarrow s^*_2 : S_2$$

$[s^*_1]$ and $[s^*_2]$ typically occur in a non-empty condition set Γ. If Γ is non-empty, the conditions are conjunctively added in the antecedent of the constraint. For example:

$$\Gamma = \{s_1 <_t s_2, s_1 =_s s_2\}$$

requires that situation s_1 is a temporal predecessor of s_2 at the location of s_2. Then we may have a constraint of the form:

$$C_1 = s^*_1 : S_1 \wedge s^*_1 <_t s^*_2 \wedge s^*_1 =_s s^*_2 \Rightarrow s^*_2 : S_2$$

When the situation types are connected by some constraint, so are the situations that are of these types respectively. The regularities of a distributed system are represented by the constraints of the complete model of that system as a whole. Information flows along these constraints at the system level. The constraints contain information what other kind of situation is involved here given some antecedent situation.

Constraints *are* regularities in the world (or supposed regularities in a possible world). *Descriptions* of constraints are pieces of informational content.

Thus, $[S_1 \Rightarrow S_2]$ is an infix notation for an infon:

$$\langle\langle \Rightarrow, S_1, S_2 \rangle\rangle.$$

Some *general principles* hold of constraints and their relation to other constraints, at least:

(i) Veridicality,
(ii) Transitivity,
(iii) Additivity,
(iv) Exclusion,
(v) Contraposibilty.

(ad i)

Constraints are *veridical*:

> Given $s_1 : S_1$ and the condition(s) of the constraint *there is* $s_2 : S_2$.

Foremost, constraints are objective regularities in real situations. One can think of possible constraints in counterfactual scenarios, in these, then, these constraints have to be veridical. Agents may *behave* as if they belief some constraint to be in place which is not. This error of believing possible constraints to be real has to be dealt with in an account of action and attitudes [§7].

(ad ii)

Constraints can be sequentially combined (a.k.a. Dretske's 'Xerox Principle', cf. Dretske 1981: 57), i.e. constraints are *transitive*:

$$C_1 = S_1 \wedge \Gamma_1 \Rightarrow S_2, C_2 = S_2 \wedge \Gamma_2 \Rightarrow S_3 \rightarrow$$

$$C_3 = S_1 \wedge \Gamma_1 \cup \Gamma_2 \Rightarrow S_3$$

Information flow includes, at least, the *transitive closure* of the constraints of a given situation.

(ad iii)

Constraints are *additive*:

$$C_1 = S_1 \wedge \Gamma_1 \Rightarrow S_2, C_2 = S_1 \wedge \Gamma_2 \Rightarrow S_3 \rightarrow$$

$$C_3 = S_1 \wedge \Gamma_1 \cup \Gamma_2 \Rightarrow S_2 \cap S_3$$

All constraints applicable to a situation apply at once. The linked situation types are instantiated in a single situation which realizes *all* these types. Supposedly natural constraints are consistent. Conventional constraints certainly have the potential to land an agent in an inconsistent situation after all have been followed.

(ad iv)

A description of a distributed system by a set of constraints should, therefore, be *consistent*, otherwise either (i) the union of the conditions being unsatisfiable *blocks* extracting a consequent situation type, or (ii) the consequent situation might be inconsistent, which should be allowed – if at all, in some dialetheism – for a few very special cases of unavoidable antinomies only. As a transitory stage of theory development collecting supposedly incompatible constraints on a situation type may be acceptable (using some paraconsistent logic), the inconsistency of the constraint set being an occasion for belief or theory revision. *Prima facie* the set of applicable constraints to a situation type should be consistent.

If some situation type *excludes* another situation type being present, this has to be expressed by the conditioning infon of the inferred type in an *exclusion constraint* being a negative infon or using a relation which stands in contrast to the relation to be excluded.

Simplified example: if it rains, a lit candle will not burn (if lit in the open etc.). So:

$$[s \mid s \Vdash << \text{🌧} >>] \Rightarrow [s \mid s \Vdash << \text{🕯}, F >>]$$

This is an exclusion constraint. Exclusion constraints are no new type of constraint, but constraints enforcing an absence (by using negative infons). Exclusion constraints may be assumed for a situation type to enforce consistency, if need be by theory revision.

(ad v)

Information flow by constraints should then also support some form of contraposition. Constraints are *contraposible*:

$$(s_1 : S_1 \wedge \Gamma_1 \Rightarrow s_2 : S_2) \wedge \neg\, s_2 : S_2 \rightarrow$$

$$\neg\, s_1 : S_1 \vee (\exists i \in \Gamma_1)(s_1 \nVdash i)$$

If some agent knows some constraint supposedly applicable in a situation of this type, and the supposedly contained

information cannot be gathered, then either one of the additional conditions of the constraint has not been supported by the given situation, or this situation was not of the antecedent type, after all. Or, again, theory has to be revised.

A collection of applicable constraints in a situation can contain information about *several* situations by (i) additional conditions Γ in the applicable constraints, or (ii) conditions in situation types that refer to further situations.

For example: Let the consequent situation type in a constraint be:

$$S_4 = [s \mid s \Vdash \varphi \wedge (\exists s_2)(\neg\, s =_s s_2 \wedge s <_t s_2 \wedge s_2 \Vdash \phi]$$

Then the information contained in the antecedent situation given the constraint will not only be that *this* situation makes φ true, but that there will be some *further*, locally distinct later situation which makes ϕ true.

Statements about the spatial, temporal or mereological relations between situations can be made true by larger situations of which the related situations are parts. In any case they are made true by the maximal situation of which they are parts: the world. Thus, statements of such relational conditions like $s_1 <_s s_2$ – for instance when used as conditions in constraints – are short for truth-making statements (the conditions being made true by the embracing world). Condition sets Γ in constraints involve such truth-making conditions for the situations relevant to the constraint.

For example: for real situations s_1, s_2, which as real situations are parts of $w_@$ (i.e. $s_1 \prec w_@$, $s_2 \prec w_@$),

$$s_1 <_s s_2 \text{ \textit{is short for}: } w_@ \Vdash s_1 <_s s_2$$

In case we want to talk about merely possible situations the role of $w_@$ is taken by that merely possible world the merely possible situations are part of. As situations can occur in infons any situation or world can make infons true which are *about it*. Thus, in the example given:

$$w_@ \Vdash \Gamma \text{ with } \Gamma = \{ s_1 <_s s_2, s_1 \prec w_@, s_2 \prec w_@ \}$$

Constraints are informational links and information *channels*. Descriptions of constraints are built up by descriptions of *information units*: infons and situation types in their relations. Only meta-representational constraints contain sentences or other representations. Meanings of sentence types are such meta-representational constraints, which, of course, have to mention the sentence constrained [cf. §5].

Some constraints are natural statistical or lawlike regularities. Other constraints are conventional regularities within a community of cognitive agents. Conventional word meaning exemplifies this second type. Both types are objective in the sense that the dependencies between the covered situation types obtain whether anyone thinks about this or not. Constraints *exist* whether known or not.

In the face of natural laws which cover in some respect every situation, every real situation and any object which is a constituent of them *carries* information about some other

situation or some object of some other situation. *Informational dependence* is everywhere. It corresponds to reality being covered by universal lawlike regularities. Only in relation to regularities does informational dependence exist. Its ubiquity, given universal lawlike regularities, when taken in isolation, however, corresponds to unimportance. Information *extraction*, on the other hand, only occurs when some information processor is attuned to some constraint or some cognitive agent knows some constraint, which is then exploited in a situation to extract information about some other situation or parts of that situation. Carrying information matters if exploited in information extraction. Semantics and 'reference' in the narrow sense require *users equipped with a code* relative to which a signal refers to something. Cognitive Science explores information extraction as subjective information flow, given a corresponding conception of 'cognitive agent'. This is the proper use of the idea of 'information flow'.

Although it is possible to view natural science as study of objective information flow under constraints a.k.a. 'natural laws', because the notion of information extraction has no application when applied to natural effects and ordinary objects this seems unilluminating (a surface on which a stone is dropped does not process information in any sense – without broadening the concept of 'information processing' to become useless in Computer Science and Cognitive Science). ST stresses the objectivity of information and informational content of representations, and grounds this conception in an ontology. Nonetheless, 'information' in ST appears as an *epistemic commodity*. The perspective in which ST talks about 'information flow' always has some active information extractor (say, a cognitive agent) in view. Information is objectively 'out there', but this is important only with respect to those being able to extract it. Re-describing physics in terms of 'information' as basic concept, or assuming information as an ultimate ingredient of (micro) reality, or even the universe as basically a (quantum) computer might be an exercise in theory re-organisation or deriving natural laws from deeper principles of information granularity and information processing (cf. Davis & Gregersen 2010, Siegfried 2000), but serves no explanatory purpose outside of physics in absence of a theory of information extraction by cognitive agents.

Informational links can be static: some *a* having property P_1 carries the information that some *b* has property P_2. Information *flow* in the narrow sense takes time. This can be due to some constraint containing the condition that the consequent situation type is instantiated by a *later* situation. The theoretically most interesting cases are those where some information processor or cognitive agent *extracts* information from a situation. Even if there is only a static informational link, information *flows* by the information extractor building new representations for this information, and updating its representational reservoir. The core case of information flow is information extraction.

To model information flow in Cognitive Science we need to consider *a cognitive system, which* is a system able to know or to process information. It is able to extract digital information from analogue representations of its environment (by

means of transduction). The system then can use its initial information to derive more information by some mechanisms, namely by being *attuned to constraints*.

For a cognitive system *a* with prior information Λ a part b_1 of a distributed system being P_1 carries the information that another part b_2 of that system is P_2 if *a* could legitimately infer from (i) the constraints of the distributed system, (ii) from b_1 being P_1, and (iii) *a*´s prior information Λ (but not from Λ alone) that b_2 is P_2. So, the cognitive system reasons along the constraints and given partial knowledge of one end of the system derives information about another part of the system. This reasoning uses a *representation* not only of the system as a whole but also of the system's parts and their properties. In this kind of information flow representations are crucial, although *how* the cognitive system represents need not be part of an ST analysis, which proceeds in terms of external content.

"Representation" should be *defined* referring to the role of a state type of a cognitive system in information flow: a *representation* of a cognitive system is a state of a type which was selected (in the cognitive systems coping with the situations it finds itself in) because of its informational content, to be *used* by the cognitive system in information extraction (cf. Millikan 1989). The selection process may be evolution or human design. The role of a state in information extraction *after* tokening characterizes a representation, not the occasions (antecedent conditions) of its tokening. A cognitive system may also extract information in a situation by exploiting both its representational resources as well as its own functional architecture or *design* (cf. Pylyshyn 1984). Design by a creator (of a technical system) or by evolution (of an organism) adapts such a system to the constraints of its typical environment. Design states are reliable information carrying states selected in the design process; given them a system can enter a new state appropriate to a changed situation without representing this change as flow of information. A *situated* cognitive system can extract information in situations of its *cognitive niche* without completely representing the constraints holding for these situations (cf. Plotkin 1997). Adaptive success of a property of an animal encodes reliable information about the environment of the animal in that property, without any requirement that the animal can cognitively access this information. From the outside the changes in the system can be described as being attuned to the constraints of relevant situations, i.e. as information flow. Representations, in contrast, are in general reliable information carrying states *selected* by a cognitive system because of their role in keeping track of its environment and its own states, and the cognitive system accesses their representational content (cf. Drestke 1981, Millikan 1984). Being attuned to *represented constraints* constitutes all modes of *inference* as information flow. But not *vice versa*: inference requires a cognitive agent, information flow does not. The idea of situated information extraction and inference fits to the recent emphasis on *embodied cognition* in the cognitive sciences (cf. Wheeler 2005, Barrett 2011).

In general: Information flow involves generic infons in situation types used in constraints linking them under conditions.

Let us consider an example: Smoke means fire. That is: If S_1 is the type of situations where smoke is present, and S_2 is the type of situations where there is fire, these situations are linked by a (natural) constraint. An agent can pick up information (that there is a situation of type S_2) by observing that there is a situation of type S_1 if the agent is aware of or attuned to the constraint. Also, someone shouting "Fire!" indicates that there is a fire in the vicinity. A situation of the shouting type S_3 is linked to a situation of type S_2 as well.

Let us look at the example in more detail.

Constraints, again, are written:

$$C = S_1 \wedge \Gamma \Rightarrow S_2$$

or

$$C = s^*_1 : S_1 \wedge \Gamma \Rightarrow s^*_2 : S_2$$

where S_1 and S_2 are situation types.

Using self-references as a resource of SF situation types can be expressed succinctly like:

$$S = [s^* | \, s^* \Vdash \langle\langle \text{Smoky}, s^*, \text{T} \rangle\rangle]$$

which is the type of situations which are smoky (themselves), even shorter: $S = [s^* | \, s^* \Vdash \langle\langle \text{Smoky} \rangle\rangle]$.

The situation types mentioned may, then, be modelled:

$$S = [s^* | \, s^* \Vdash \langle\langle \text{Smoky} \rangle\rangle]$$

$$S_1 = [s^* | \, s^* \Vdash \langle\langle \text{Firey} \rangle\rangle]$$

$S_2 = [s^* | s^* \Vdash \langle\langle \text{Utters}, a^*, \text{“Fire!”} \rangle\rangle]$

with two constraints, which involve the condition of the properties being instantiated in a part of the situation (by SF rules variable [s*] has to be anchored uniformly)

$C_1 = s : S \wedge s^* \bigcirc_s s \wedge s^* \bigcirc_t s \Rightarrow s^* : S_1$

$C_2 = s : S_2 \wedge s^* \bigcirc_s s \wedge s^* \bigcirc_t s \Rightarrow s^* : S_1$

To understand the idea of information flow within this model consider the constraints and situation types just given. Suppose $s_1 : S$ (i.e. situation s_1 is of type *S*: there is smoke). Being aware of the constraint (C_1) or being simply attuned to it we have the information that there is a situation s_2 (maybe even $s_2 = s_1$) with $s_2 : S_1$ (i.e. there is fire) so that s_1 and s_2 at least overlap spatially and temporally, $\Gamma = \{s_1 \bigcirc_s s_2 \wedge s_1 \bigcirc_t s_2\}$. In the notation above [s*] has to be anchored to such a part shared between instantiating the two situation types. Being attuned to (C_2) we are disposed to assert – *ceteris paribus* – fire to be present once the thought of fire being present occurs to us, instantiating situation type S_2. Constraints being additive situation *s* is a situation in which there is smoke *and* somebody utters “Fire!”, from both of which the information that there is fire somewhere in some (proper) part s* of *s* can be extracted.

An information processor extracts information about some situation given that it is informed that a given situation is of some type and that type is linked by a constraint to some other

type (of situation).[3] The actual linking of situations is done by variable objects and parameters (where a parameter present in the two situation types is anchored to an object present in the two situations linked). The constraint (on types) captures generally what connection obtains between two (token) situations. SF employs its notation to *describe* constraints. Cognitive agents knowing some constraints represent them in some fashion. Constraints are not sentences, but regularities in some world. Existing constraints are regularities in $w_@$ (i.e. of reality).

A constraint is an *information channel* between two situations – adopting a central concept of the early syntactic theory of information (cf. Shannon 1993). In this perspective fulfilment of the antecedent of a constraint (say, $s_1 : S_{23}$) *signals* the information of the consequent (say, $s_1 : S_{28}$). One may speak instead of carrying information relative to constraints of carrying information relative to an information channel. The principles governing constraints are then principles of channel set up. Veridicality means that the channel is operational. A semantic information channel has no limited *channel capacity* by which information flows. Transitivity means that channels can be coupled sequentially. Additivity means that indefinitely many channels can operate in parallel. An information channel can be *broken* by one of the preconditions of the constraint (in Γ) not being fulfilled. Contraposition means that

3 We continue, first, the elucidation of ‘constraints’ and ‘information extraction’. The notions of ‘information processor’ and ‘agent’ used will be clarified subsequently.

the channel is broken or there was no channel access in the first place.

The syntactic theory of information works with some key concepts, including (i) the surprise value of a signal as measure of information, (ii) the capacity of a channel, (iii) disturbances of information conveyance by the channel due to 'noise', which concepts are all relative to (iv) a coding scheme. All these concepts measure a comparative value: of surprise in contrast to other signals, of amount of noise relative to channel capacity, which can be compared to other channels and definitionally depends on the coding scheme.[4]

These concepts can in a lose analogy be applied to information flow by constraints, information extraction by agents:

(i) the *surprise value* can be assessed by the frequency the agent confronts a situation of the antecedent type and conditions of a constraint, relative to the average frequency of situation types encountered; the more regular a fact the less informative a signal that allows to predict it; the surprise value should not be equated with the relevance of the information for the agent, as this depends on its goals (in a situation);

[4] In the paradigm example of Morse Code the three types of signals ('long', 'short', 'pause') are used to code letters, the less used carrying more information (surprise value) than the often used, the wire (as channel) has a conveyance capacity of signals per time unit, malfunction in the wire or errors by the sender are noise to the receiver.

(ii) the *capacity* of information extraction (information relative to time) is limited by the constraints the agent knows or is attuned to, and by the agent's capacity to store and process information in some time interval;

(iii) information extraction can be *noisy* as it can be disturbed by failure in perception ('noise' in discerning the antecedent conditions of a constraint) and inattentiveness and similar failures/malfunctions of the agent; even constraints an agent knows or is attuned to may not be properly exploited to extract information due to 'noise' in the agent.

(iv) the *coding scheme* can be identified with the conceptual framework an agent is equipped with, and which determines which constraints the agent has in its cognitive reach (by knowledge or being attuned).

A complete account of information extraction by an agent of a type (say, kind of animal) needs to include an ethology of its typical environment/niche (situation types encountered) and an account of its cognitive design (e.g. memory and inferential capacities).

Linguistic *meaning* can also be analysed along such lines [cf. §5]. Constraints are involved in meaning relations: "fire" is hooked up to fire. This is a constraint linking an utterance situation type to a type of situation where fire is present. Attuned agents with respect to this constraint understand the exclamation “Fire!”. An account of literal and metaphorical meaning, therefore, can be based on meta-linguistic constraints, and (common) knowledge of constraints. With respect to natural language communication the presence of a coding scheme (including semantics), channel capacity (in an interaction and the capacities of speakers and hearers), surprise value and noise are obvious.

The objective information *present in a situation s* is the *closure* of the set of infons made true by *s* given *all* constraints and inference rules, relative to a conceptual scheme in which these infon and constraints are expressible. This follows from the first half of *Barwise's Principle*: ‘information travels at the speed of logic’.[5]

The *subjective information* a cognitive system *a* in a situation *s* has *about* situation *s* is the closure of *a*´s representations of *s* given the constraints that *a* is aware of or these in combination with the constraints *a* is attuned to (in case of enthymemic information extraction where the missing pieces are provided by *a*'s build-in information extraction). Subjective information is known information, and knowledge – as the second half of *Barwise's Principle* asserts – does *not* travel at the speed of logic. A cognitive system *draws* only those consequences (extracts only so much information) as the *known* inference rules allow. A cognitive system employs some

[5] On such closure conditions and the problem of idealization therein cf. §6.

representational/conceptual scheme, and *can have* only that information which is expressible in this scheme. The concept of ‘subjective information’ is central to the analysis of attitudes [in §7].

The information flow a cognitive system is *attuned to* is the combination of that system's subjective information extraction and the objective information extraction due to that system's design.

Extracting information by using or being attuned to constraints also means that the extracted information *obeys* the constraints. In this sense information extraction is a *constraint satisfaction problem* (well-known from theoretical computer science and algorithm design).

Parts of a theory of *intentionality* and the attitudes are part of a theory of information flow. Individuating an agent as an information processing cognitive system employs the format of SF to describe the information the agent subjectively possesses or is attuned to. If some entity occurs in such a description the agent is implicitly described as possessing in the agent's ontology the corresponding category. The description also asserts that the agent extracts information about *these* specific entities. What is not asserted is that the agent uses the representations used in describing the agent. Information extraction extracts the objective commodity information. SF descriptions by default take a 3rd person point of view. How, within the agent, the agent's information extraction happens *representationally* requires an extended analysis of an agent's representational system, employing extended SF-resources like attitude ascriptions, quotations and sets Λ of information available to the agent either objectively or as the *relatum* of agent knowledge/belief. For many (simple) agents or contexts such complications may not be required. Even the limited logical closure of subjective information may proceed by describing in *objective* terms the agent's set of logical information available. For agents with intentional attitudes and a meta-mind, however, such complications play an important role in some contexts.

Conceptually SF distinguishes between *information processors* in general, which group includes technical systems, and *cognitive agents/systems*, which *use representations* in their cognition. Persons and many animals are cognitive agents/systems. In technical systems representations are processed – and so one may explain their behaviour and information extraction by reference to these representations – but *they* do not *use* representations (in the proper sense): they are built by persons who designed their representational resources to have some representational algorithms and problem-solving behaviour implemented. The representations are not representations for them, but for the designers. Designed information processors are semantic artefacts: they have states which represent, but in the way a book does: for a reader or interpreter. Nonetheless, describing them in terms of information flow provides a useful higher-level description of their workings, while a physical description – not available in almost all cases, anyway – supposedly would be unwieldy.

With this kept in mind ST may talk loosely of 'agents' in general statements (as has become habit in software engineering and cognitive science) and disambiguate if need be.

The next step in the analysis of information flow in that direction is to look at information extraction *via* cognitive agent's attitudes [covered in §7.]

ST from the start (Barwise & Perry 1983) introduced analysis of information flow by constraints. (Perry & Israel 1990) analyse information flow in the design and architecture of complex systems. A more advanced analysis of information flow can be found in (Barwise & Seligman 1997).

§5 Basic Analysis of Situated Meaning

The meaning of an expression is a set of constraints. Understanding a meaningful utterance in a situation is a form of information flow. Language use is situated. Meaning, therefore, has to be understood and analysed as situated information extraction given an utterance – typically of a well-formed sentence token – in a situation.

The meaning of a declarative sentence is a situation type, typically with variables. This sentence can be used in a *situation of utterance* to make an assertion, which typically involves anchoring the variables to the situation of usage. The anchored infon $f[\varphi]$ is what is understood as the *content* of the utterance. The propositional content of the utterance consists in the claim that the *described situation*, which typically will not be identical to the situation of utterance, but can be identical to the situation of utterance, is a real situation which makes $f[\varphi]$ and its consequences true, i.e. that a part of the world is as the infon says. This claim itself may be true or not, the speaker carries the burden of justification.

In situations of utterance there are always certain parameters present (whether explicitly mentioned or presupposed) which define *roles* in communication: the speaker, the audience, the situation (time and location) of the utterance, the utterance itself. The parameter [now*] refers to the time of the situation, and is used in the information content of a present tense

sentence. Deictic expressions can directly refer to parameters (e.g. “here” refers to [here*]).

If Fred utters declaratively towards Linda on the 12^{th} of June in *s* “I mailed you the letter by express yesterday”, a simple analysis using the roles of speaker*, audience*, time* and an anchor *f* in *s* yields:

(i) $i = \langle\langle \text{ExpressMail, speaker*, audience*, } \boxtimes, \text{ time}_1\text{*} - 1 \text{ day, T} \rangle\rangle$

(ii) $i_1 = \langle\langle =, 12, 11{+}1, \text{T} \rangle\rangle$

(iii) $s \Vdash \langle\langle \text{KNOW, audience*, } i_1, \text{T} \rangle\rangle$

(iv) $S_1 = [s \mid s \Vdash \langle\langle \text{ExpressMail, sender: } a_1\text{*, recipient: } a_2\text{*, item: } a_3\text{*, time}_1\text{*, T} \rangle\rangle]$

(v) $S_2 = [s \mid s \Vdash \langle\langle \text{Get, recipient: } a_2\text{*, item: } a_3\text{*, time}_2\text{*, T} \rangle\rangle]$

(vi) $C_1 = S_1 \wedge \{\langle\langle =, \text{time}_2\text{*, time}_1\text{*} + 1 \text{ day, T} \} \Rightarrow S_2$

(vii) $s \Vdash \langle\langle \text{KNOW, audience*, } C_1, \text{T} \rangle\rangle$

(viii) $f[i] = \langle\langle \text{ExpressMail, Fred, Linda, } \boxtimes, 11^{th} \text{ June, T} \rangle\rangle$

s is the *situation of utterance*. The anchored infon is made true by the *described situation* s_2 of that utterance (on June 11^{th}), for which

$$s_2 \Vdash \langle\langle \text{ExpressMail, Fred, Linda, } \boxtimes, \text{T} \rangle\rangle$$

The meaning of the sentence used by Fred provides the relation between the situation of utterance and the described situation. And from this anchoring of Fred’s statement to the situation of utterance (Fred's *speaker meaning*) Linda because of her knowledge (iii) and (vii) infers:

<<Get, Linda, 🖂, today, T>>.

So, Fred's statement means indirectly that Linda gets the letter today. It means that because of a semantic constraint (the type meaning φ of the sentence) and a causal constraint on a regularity in the social world (i.e. the typical time frame of the express mail service).

To emphasise the *relation character of meaning* one may express the general pattern of the example thus:

s_1[I mailed you the letter by express yesterday]s_2

where:

s_1 $\Vdash$<<ASSERT, speaker*, "I mailed you the letter by express yesterday", audience*, time*$_1$: date$_1$>>

s_2 $\Vdash$ <<ExpressMail, agent: speaker*, recipient: au dience*, object-type: 🖂, time*$_2$: time*$_1$ – 1 day>>

The relation depends, of course, on the words used and corresponding analytic knowledge (like: "express mail" *defined* as mail taking one day). When Fred uses the sentence with this meaning on the 12th of June towards Linda, we anchor the speaker* and audience* roles accordingly, and get our example content above.

SF follows Quine's principle of 'shallow analysis': How shallow or deep an analysis of a statement has to go (in relevant variables or decomposition of complex infons) depends, of course, on the communicative content and its situational impact to be explained.

Putting situation of usage (utterance situations) into focus, with anchoring (indexical) parameters in some unit of content, ST fits best to model *speech acts*. Speech acts cannot be defined syntactically, but only in what a speaker does with language in a situation. Intentionally uttering a sentence constitutes the locutionary act, the anchored sentence content in the situation of utterance constitutes the illocutionary act, in combination with the situational fulfilment of the felicity conditions of the speech act type. ST analysis always combines semantics and speech pragmatics. In case of imperatives, for example, in s_1 the situational impact of an utterance (e.g. "Close the door, please!" referring to a follow up situation s_2 where <<closed, door>> obtains) depends on the roles of speaker*, addressee*, and the mutual knowledge of authority rules and causality constraints in s_1. The whole discourse situation, of which s_1 and s_2 are temporal parts, anchors anaphora ("Now it is closed", i.e. the door) as well. A successful speech act *changes* the situation type (by new obtaining infons: a door being closed on command, a belief being acquired by the audience etc.).

Successful speech act types can be *defined* in ST as transformations of situations (the pre-conditions specified by a situation type, the post-condition specified by a situation type).

Unsuccessful speech acts have been intended as being of a type while failing either in the pre- or post-conditions. The definitions establish analytic links for the performative vocabulary: “assert”, “command” etc.

For example:

Assertion as speech act type has as pre-condition in s_1, at least:

$s_1 \Vdash \{$ <<UTTER, speaker*, α>>,

<<BELIEF, speaker*, $f[cont(\alpha)]$>>,

<<HasReasonFor, speaker*, claim: α, reason: γ>>$\}$

with further felicity pre-conditions (like speaker and audience sharing a language), and as post-condition, something like, but not so simplified as:

$i_1 =$ <<BELIEF, hearer*, $f[cont(\alpha)]$>>

$i_2 =$ <<UTTER, speaker*, γ>> with: $(\exists s_2)\ s_2 \Vdash i_2$

$s_3 \Vdash \{ i_1,$ <<CAUSE, i_2, i_1>>$\}$ with: $s_1 <_t s_2$, $s_2 <_t s_3$

depending on whether the goal of assertion is that the audience understands the speaker and his reasons, or the audience acquiring a belief because of the assertion and its justification. A speech act often develops over an indefinite sequence of situations (e.g. an exchange of reasons for and against accepting some belief). Some types (like Baptizing) may be less

involved in their duration and conditions than others (say, Commanding).[6]

In general: A sentence type has a (generic) meaning. A sentence token used in a declarative statement in a situation expresses speaker meaning in that situation. Given the objective content of the sentence type (an infon), meanings are not just in the head of speakers, they relate a speaker to some objective content (an anchored infon). ST endorses semantic *externalism*. The meaning of the statement is a relation (a *constraint*) between the *situation of utterance* (involving speaker, audience, time etc.) and situations of the type that make the anchored infon true (the *described situation*, which can be identical with the situation of utterance). An audience knowing the meaning of the sentence type and the situation of utterance, typically by being present there directly or indirectly (in case of written statements, say), can infer the specific content of the statement. By this the audience can understand the attitude(s) of the speaker. Speaker and audience ideally are attuned to the semantic constraints (including their preconditions and relevant variables) which constitute sentence meaning. Inference to the communicative impact of the statement understood will typically require knowledge of or being attuned to constraints on regularities in the world.

A true statement (the content of which is an obtaining infon) *refers* to the described situation (more precisely: it *refers* to

6 SF in such semantic/pragmatic analyses might, then, integrate elements of Illocutionary Logic (cf. Vanderveken 1990) and Discourse Representation Theory (cf. Kamp & Reyle 1993).

the fact corresponding to the obtaining infon, which fact is a constituent of the described situation). In ST, thus, true statements and correlated eternal sentences have *individual* reference, in contrast to the Fregean doctrine that all true statements and correlated eternal sentences refer to the truth value T. True statements and correlated eternal sentences refer to the truth-makers of their content, the content being an anchored infon, the *reference* the corresponding fact. False statements and correlated eternal sentences need no reference. The described situation of a false statement and correlated eternal sentence is no real situation.

Because different true statements and correlated eternal sentences differ by their anchored infons, they differ in content (i.e. the entities occurring in the infons being their content). Therefore, even if two statements and correlated eternal sentences are logically equivalent, they need not be identical in their meaning, and thus need not be identical in their reference. This ability to distinguish the contents of logically equivalent statements and correlated eternal sentences applies also to false statements and correlated eternal sentences.

Example: If Fred hat said "I mailed you the letter by express yesterday, and a vixen is a female fox", he would have used a logically equivalent sentence, because the second conjunct is analytically true (in all situations), but this sentence speaks of foxes, and the other sentence does not. The content infon of the second sentence has much more *structure* than the content

infon of the first sentence. Infons and informational content as meaning are *more fine-grained* than logical equivalence.[7]

Because infons are sentence contents, and identity of meaning is stricter than logical equivalence of sentences, infons are *finer*-grained – not as fine-grained as representations, because they are external contents, not inner modes of representation. Representations are ultimately fine-grained as the mere exchange of two co-referential representations can make a difference [cf. §7]. Infons contain entities which are named when *noting down* an infon in SF, but any co-referential name can be used in noting down an entity which is contained in an infon. Descriptions of infons ST strictly distinguishes from the infons themselves, which are not linguistic entities.

Nothing in the set up excludes that two or more different token meanings can be generated from an utterance. In these cases the utterance was *ambiguous*. Ambiguity of sentence type meaning in general contributes to the *efficiency of language*: using limited linguistic resources to express way more speaker meaning. In ST the situatedness of token meaning in combination with type meaning ambiguity explains this efficiency. SF is suited for the ambiguities to be resolved by anchoring. Success, however, is not guaranteed in all cases.

[7] This echoes Carnap's move to 'intensional isomorphy' (Carnap 1947: §§14-15) as specification of content in face of Church's argument that all true statements must have the same reference, a.k.a. 'slingshot arguments' (cf. Neale 1995).

And nothing in the set up excludes that the transformation to token meaning *crashes* (due to conflicting constraints) or does *not get off the ground* (due to lack of applicable constraints). In these cases the utterance lacks meaning, which does not exclude that information can be extracted from *this failure*. An issue for an advanced analysis should be how an audience understands non-well-formed utterance (e.g. ungrammatical sentences), as we encounter regularly in everyday discourse.

The situatedness of language usage involves aspects of intonation, contrast, audience's expectation etc. These aspects allow to extract *further information* from an utterance by *implicature* and related pragmatic phenomena.

For instance, suppose that the utterance of "Mary kissed Linda" in s_1 deliberate stress is put on "Linda", then the information extractable includes not just i_1 = <<Kiss, Mary, Linda, s_2>> and i_2 = <<$s_2 <_t s_1$>> but also <<Expect, audience*, <<Kiss, agent: a*, patient: Linda>>, F>> or something more fine-grained. These aspects are topics for a more advanced analysis of situated language use, which integrates aspects like intonation as ingredients of transforming sentence type meaning into token utterance meaning. One issue will be where to draw a semantics/pragmatics-distinction, i.e. which parts of the information extracted are due to meaning constraints (conventions) and which are due to pragmatic constraints (say, conventions covering intonation or contrast).

Part of such an advanced analysis will also be *epistemic aspects* of a shared situation – the shared *background or*

contextual knowledge (cf. Stalnaker 2014), which are always involved in extracting information from an utterance.

Situation semantics is best suited to explain the transition from sentence type meaning to statement token meaning in a situation, and a correlated eternal sentence. The linkage by constraint between the situation of utterance and the described situation constitutes part of the meaning of the sentence type. Nothing in this model excludes that, at least, the type meaning of an eternal sentence (an anchored sentence) can be understood in the form of a *disquotational* theory of truth. Knowledge of meaning consists in part in knowing those constraints that correspond to the disquotational equivalences of a theory of truth for the language in question. In fact, considering a situation *appropriate* for an utterance of α with $f[cont(\alpha)] = \varphi$ most likely contains such 'disquotational' knowledge: the constraint constituting (partially) the meaning of α makes use of a situation type S where most likely $cond(S) = \varphi$. Knowing the constraints in the meaning of a sentence type α consists (partially) in knowing a truth condition in the guise of a relation between infons and sentence use. In cases like above, where $cond(S) = cont(\alpha)$, this knowledge is – despite the difference in format between an infon and the right-hand side sentence of a truth-condition – roughly 'disquotational'. If the situation of utterance of a statement is not appropriate, then the content of the statement will not obtain, since the described situation making it true will not be a real situation.

Like truth-conditions can be informative in using another sentence α_2 on the right-hand side of a truth-condition of a sentence α_1 ($\vDash[\alpha_1]$ is true in $L \equiv \alpha_2$), which yields informative analytic sentences (of the type $\vDash\alpha_2 \supset \alpha_1$), constraints can be informative in linking situation types with quoted expressions to situation types the conditioning infon of which contains not just the transparent referents of the expressions (i.e. not just *Cat* for "cat"), constituting substantial semantic knowledge of appropriate situations of usage.

[Constraint C_2 in the fire example in §4 is almost disquotational.]

ST, although proposing a semantics of objective external content, should be considered compatible with an *internal semantics* of *knowledge of meaning* in terms of a theory of truth for a language (like Larson & Segal 1995), and, therefore, *partially* with semantic internalism (cf. Chomsky 2005), and even *conceptual atomism* (cf. Fodor 1998), which agrees with ST on externalism of semantic content and the role of reference to representations in the analysis of the attitudes [cf. §4].

The ontological categories and the meaning constraints an agent knows constitute the *conceptual scheme* of that agent. Humans as users of natural language possess a fine-grained conceptual scheme. Understanding the actions of a person requires at times to refer to the representations used by the person or to represent their cognitive content by referring to fine-grained relations (i.e. those of a tuple of relations the expressions of which in natural language although co-referential in a situation are not synonymous). Categories and constraints

specified by non-fine-grained informational content may be attributed to those animals which are cognitive agents. In their case the description of their cognitive content by non-synonymous but co-referential expressions forces no explanatory difference. The simplest form of a conceptual scheme posits the single category of situations and classifies them by situation types. This may suffice to explain the behaviour of some animals in situations of their ecological niche. The conditioning infons of the situation types will be specified from the ethologist's 3rd person perspective, of course. The ontological categories in this specification need not be possessed by the animal at all. The way the situation types and constraints are inwardly processed can drop out of this picture entirely. Only when the ethologist wants to explore the representational resources and design of the animal further categories enter the picture.

Constraints are one way to describe meaning. Word meaning also serves to classify objects. Even if predicates can typically not be defined by sufficient and necessary conditions (except some cases like "bachelor" and words referring to some designed artifacts built according to plan) a partial definition of a predicate can be captured by defining a type:

$$[\ a \mid \langle\langle \text{Herbivore, a} \rangle\rangle, \langle\langle \text{Ruminant, a} \rangle\rangle, \ldots]$$

may be the type COW. Semantic hierarchies can then be expressed by an algebra of types, e.g. ANIMAL $\subseteq$ COW, or by analytic links in the form of *rewriting rules*, e.g. HERBIVORE $\rightarrow$ ANIMAL. This resembles *Feature Semantics*.

Constraints can also be used to model *metaphorical meaning* (as correspondence rules between situation types taking the audience from the situation of utterance first to the *literally* described situation which then metaphorically corresponds to the *intended* described situation). The metaphorical reading is triggered when the literally reading (e.g. <<Lioness, Linda>>) clashes with situational background (e.g. <<Woman, Linda>>), but speaker and audience share knowledge of the applicability of (a stock of) metaphors. The constraints constituting metaphorical correspondence involve a meta-linguistic element: they are about a description which cannot be taken literally.

As a general scheme [using notational conventions of §2, §3, §6]:

$$\Gamma_M = \{\, w_@ \Vdash \langle\langle \text{Sortal}^*_1, a^* \rangle\rangle \supset \langle\langle \text{Sortal}^*_2, a^*, F \rangle\rangle,$$

$$w_@ \Vdash \langle\langle \text{Expresses}, \delta, \text{Sortal}^*_2 \rangle\rangle,$$

$$w_@ \Vdash \langle\langle \text{Sortal}^*_2, a^* \rangle\rangle \supset \langle\langle \text{Property}^*_1 \ldots, a^* \rangle\rangle \}$$

$$C_M = \quad S_1 = [s \Vdash \{\langle\langle \text{Sortal}^*_1, a^* \rangle\rangle, \langle\langle \text{DescribedAs}, \delta, a^* \rangle\rangle\} \wedge \Gamma_M \Rightarrow$$

$$S_2 = [s \Vdash \{\langle\langle \text{Sortal}^*_1, a^* \rangle\rangle, \langle\langle \text{Property}^*_1 \ldots, a^* \rangle\rangle\}]$$

C_M outlines the scheme for a general metaphorical mapping. A metaphorical mapping with a description which uses a sortal predicate expressing a sortal property that contradicts another original sortal property will be resolved by still applying the original sortal *and* extending the characterization of the object by those properties which the second (only metaphorically applicable) sortal implies.

So, in case of Linda being described as "lioness",

$$w_@ \Vdash \quad \langle\langle \text{Lioness}, a^* \rangle\rangle \supset \langle\langle\langle\langle \text{Strong}, a^* \rangle\rangle \wedge \langle\langle \text{ProtectiveOf}, \text{offspring}, a^* \rangle\rangle\rangle\rangle$$

$$w_@ \Vdash \langle\langle \text{Woman}, \text{Linda} \rangle\rangle \supset \langle\langle \text{Lioness}, \text{Linda}, F \rangle\rangle,$$

$$w_@ \Vdash \langle\langle \text{Expresses}, \text{“lioness”}, \text{Lioness} \rangle\rangle,$$

$$w_@ \Vdash \langle\langle \text{Lioness}, \text{Linda} \rangle\rangle \supset \langle\langle \text{Strong} \ldots, \text{Linda} \rangle\rangle$$

$$s \Vdash \{\langle\langle \text{Woman}, \text{Linda} \rangle\rangle, \langle\langle \text{DescribedAs}, \text{“lioness”}, \text{Linda} \rangle\rangle\}$$

$$s \Vdash \{\langle\langle \text{Woman}, \text{Linda} \rangle\rangle, \langle\langle \text{Strong} \ldots, \text{Linda} \rangle\rangle\}$$

Linda will be understood as being a woman (not a lioness) who is strong and protective of her offspring, i.e. her child, given a further semantic inference by:

$$w_@ \Vdash \langle\langle\langle\langle\langle\langle \text{Offspring}, a^*_1, a^*_2 \rangle\rangle \wedge \langle\langle \text{Human}, a^*_1 \rangle\rangle\rangle\rangle \supset \langle\langle \text{Child}, a^*_2 \rangle\rangle\rangle\rangle$$

A similar account might be given for *Conversational Implicatures*.

In general, shared situational background knowledge Λ serves in disambiguation and the proper understanding (reading or hearing) of statements, which can be understood in different ways. The conditions Γ in constraints help singling out the appropriate situational context.

Knowledge of meaning needs to be shared knowledge in a linguistic community. Speakers possess *common knowledge* that each other knows the conventions of usage (cf. Lewis 1969). SF allows circularity: infons can refer to themselves and situations that make them true. Shared knowledge of *a* and *b* of some infon φ made true in a situation *s* can thus be defined as *situational common knowledge*:

(i) $s \Vdash \varphi$
(ii) $\Gamma = \{i \mid s \Vdash i\}$
(iii) $s \Vdash \langle\langle \textsc{know}, a, \Gamma \rangle\rangle$
(iv) $s \Vdash \langle\langle \textsc{know}, b, \Gamma \rangle\rangle$

$\varphi \in \Gamma$. As *a* knows all facts of *s a* knows that *b* knows all facts of *s*, including *a* knowing that *b* knows all facts of *s.* The circularity rests in Γ, because: $\langle\langle \textsc{know}, a, \Gamma \rangle\rangle \in \Gamma$.

(Knowing a set of infons collectively means knowing them all individually.)

The analysis of meaning (as ‘Situation Semantics’) starts as a central topic in ST in (Barwise & Perry 1983, Barwise 1989), and has resulted in many applications of ST in linguistics (cf. Kratzer 2023)

§6 Basic Principles of Situated Logic

Infons and truth-making have their own logic. Their logic ('infon logic') comes not as a finished formal system, but being part of SF comes as an open-ended list of logical principles that apply to infons [therefore the capitalized abbreviation "IFL" used for it here sometimes, should be taken differently from others like "ZFC".]. SF includes a logical system for sentences and consequence (supposedly incorporating principles of FOL, SOL, and of alethic, epistemic, temporal modal logics). The details are not completely worked out here, but at times only hinted at. The focus lays on infon logic (i.e. the logical structure of infons and the logical relations between infons). Like ST bases meaning as a form of information flow, ST strives at an "information-based theory of inference" (Barwise & Etchemendy 1990: 35), understood as elucidating the *consequence* relation in terms of *constrained dependency in informational content*. ST conceptualizes its analysis of meaning as a kind of information flow as 'situated language' [cf. §5]. Similarly, it conceptualizes its analysis of consequence and inference as kinds of information flow as 'situated logic'.

This semantic elucidation of 'consequence' using SF-resources should not be confused or taken for an *algorithmic* elucidation of inference, which has to be added for a complete account of inference in cognitive agents. A model in formal ontology – of which employment of SF is an example – is not by itself a *computational* model. Compare: There is a world

of differences between elucidating 'order' in set theory and ordering algorithms in practical computer science.

The categories of SF are characterized both by ontological principles and logical principles. These principles have, of course, to be consistent with the logical principles for sentences, as infons are their contents. The structure of complex information units in its relations to basic information units resembles the recursive truth-conditions on complex sentences. Some of these well-known recursive conditions may not apply, because situations are partial and infons can be non-well-founded. IFL ≠ FOL, and IFL ≠ SOL. Closure conditions on information units, however, may be stronger than closure conditions for representations (linguistic or otherwise) that a cognitive agent processes.

Infons stand in logical relations. One can combine them, or make quantificational claims concerning them. One may put connectives as known from propositional logics *between* infons, and quantifiers known from quantificational logics in front of them – as has been done sometimes in the ST tradition. This neglects that infons are *contents* of sentences which contain the logical vocabulary. If the logical vocabulary is put outside the infons (i.e. outside the content carriers) – *where* is the logical content? Logical connectives and quantifiers have to occur within *complex* infons. These logical connective and quantifiers are the *objective functions* denoted by their linguistic labels, e.g. [∧] in an infon is the *function* which takes two infons to a complex infon which is made true only by those situations which make the conjoined infons both true. Quantifiers are functions on generic infons and anchors, again similar to model theoretic truth conditions of quantified sentences given assignments.

The consequence relation [⊨] between infons has to *reflexive* and *transitive* to enable re-iteration and flow of information by the *Xerox Principle* [cf. §4].

Now one might argue: As infons are finer-grained the consequence relation has to be *anti-symmetric* as well. Because infons are finer-grained [cf. §5], they cannot be closed like sets of sentences are closed under FOL or SOL. They can be closed on laid down *analytic* links between general terms (respective their property referents). The infon <<Vixen, a_1>> implies the infon <<Fox, a_1>> because of the definition of [Vixen], and because the presence of the property *Vixen* ensures the presence of the property *Fox* in a situation. *Verum ex quodlibet*, on the other hand, introduces *new* content: The sentence [Vixen(a)] implies the sentence [Vixen(a) ∧ (Hungry(George) ∨ ¬Hungry(George))] by PC, but for infons such an implication is not acceptable, because the infon i_1 = <<Vixen, a_1>> does neither contain George nor the property *Hunger* as content. If i_1 implied

i_2 = <<∧, <Vixen, a_1>>, <<∨, <<Hungry, George>>, <<Hungry, George, F>>>>>>

the two infons would be arguably identical in content (by anti-symmetry of consequence), as the conjunctive i_2 trivially implies i_1 as the first conjunct. This way would be a way to introduce *any* content entities whatsoever into infons, which in ST contrariwise are introduced as partial, situational contents.

At most infons can be closed under:

(i) lawlike (empirical) constraints, which should be uncontroversial, and
(ii) analytic links (in the narrow sense above), which should be uncontroversial, and
(iii) rules of higher order quantification, as SF is higher order, which, thus, should be uncontroversial, and – maybe
(iv) at the propositional level some Relevant Logic (which does not endorse the ‘paradoxes of material implication’).

Presumably infon logic has to be a Relevant Logic at the propositional level. Which Relevant Logic (B, R, RM_3 DJ^dQ ... cf. Brady 2006, Mares 2004, Priest 2008) should be taken as basis for infon logic need not concern us now, but we can already note that if we have *semantic* reasons for using a Relevant Logic as backbone of infon logic, this comes in handy in case we need a paraconsistent logic to deal with paradoxes which follow from the *circularity* involved in SF’s expressive power – we may return to the same Relevant Logic, which, of course, will be paraconsistent. [§8 comes back to this issue.]

The principled alternative consists in accepting some irrelevant consequences like *verum ex quodlibet*. The content of an infon φ would seem to get diluted, but there still is a core content of φ which distinguishes φ from other (diluted) infons. One should *reject* defining infons as identical if and only if they are mutual consequences of each other. One should stick to defining infon identity by the constituents of the infon in their respective structural role [as in §3]. This way infons and informational contents are unique, as it should be, as they are abstract entities independent of formulations of individual (natural) languages. A secondary benefit of this approach will be a simpler account of closure in infon logic.

In SF noting infons uses the logical vocabulary homonymously which is used in the logical formal languages; this is harmless as infons are syntactically clearly distinguishable in SF from sentences.

Basic infons are infons with one main non-logical relation: $<<R, ... >>$

Logical Connectives and quantifiers (as functional entities) are *basic categories* in SF. The expressions for sentential connectives [∧, ∨, ⊃, ...] and operators [□, ◊, ...] are *overloaded* to connect both sentences and infons. The quantifiers [∀, ∃, ι] are *overloaded* to bind variables in sentences and variables in infons. (Remember that variables in infons are not linguistic.)

In case of conjoining infons we have the principle

(P1) $s \Vdash i_1$ and $s \Vdash i_2 \rightarrow s \Vdash << \wedge, i_1, i_2, T>>$

$i_3 = << \wedge, i_1, i_2, T>>$ is a *complex* infon (not a sentence, [∧] being a function not the conjunction *sign*). Note that in (P1) the truth-value T occurs in the conjunction, whatever truth-values occur in the conjuncts. (Remember: a situation can make a negative infon true, i.e. an infon *using* truth-value F can be made true.)

For disjunction we have principle

(P2) $s \Vdash i_1$ or $s \Vdash i_2 \rightarrow s \Vdash << \vee, i_1, i_2, T>>$

and so on. Similar to the material conditional, the infon $<< \supset, i_1, i_2>>$ contains the information that i_1 obtaining excludes i_2 not obtaining (in some truth-making situation).

Using the logical vocabulary homonymously in SF talk about situations and infons the principles become transparent:

$$s \Vdash i_1 \wedge s \Vdash i_2 \rightarrow s \Vdash << \wedge, i_1, i_2, T>>$$

or even shorter with infix notation and hiding the default truth-value T:

$$s \Vdash i_1 \wedge s \Vdash i_2 \rightarrow s \Vdash << i_1 \wedge i_2>>$$

Infix notation eases readability, one should remember, though, that (complex) infons are not (complex) sentences. So $<<i_1 \wedge i_2>>$ is not a conjunction infon, but a complex infon in which the function of conjunction, expressed by [∧], is applied to two infons. This infon is the objective content of a conjunctive sentence (a conjunction).

Recursive truth conditions mirror those of PC.

At the *basis* an infon obtaining has to explained in ontological language:

(T1) $s \Vdash <<R, x.., T>>$ if and only if the entities *x*... stand in relation *R* in situation *s*.

At the basis truth-making grounds in some fact being a part of the truth-making situation.

(T2) $s \Vdash \langle\langle \wedge, i_1, i_2, T \rangle\rangle$ iff $s \Vdash i_1$ and $s \Vdash i_2$.

and so on. Truth-making conditions for infons correspond to truth-conditions of (eternal) *sentences* the content of which are the corresponding infons. In ST: Sentential semantics supervenes on infon semantics.

Quantifiers can bind variables in generic infons: let $i_4 = \langle\langle P, x^*, T \rangle\rangle$, then there is a complex infon $i_5 = \langle\langle \exists, x^*, i_4, T \rangle\rangle$, and for a claim with respect to existing entities $i_6 = \langle\langle \exists@, x^*, i_4, T \rangle\rangle$. Similar for [∀]. [x*] is free in i_4 and bound in i_5. The presence of quantifiers in complex infons underlines that parameters and variables *in* generic infons differ from quantification in infons like i_5. The *domain* of a quantifier of a category in an infon which is not the content of a logic/semantic truth is the set of entities of that category *in the situation* which may make the infon with the quantifier true, or the set of existing entities of that category for quantifiers [∃@, ∀@]. As infons are made true by situations, which are partial, quantification is *bounded* to the entities present in a situation.

(P3a) $(\exists x^*, f)\ s \Vdash f[\langle\langle P, x^*, T \rangle\rangle] \wedge f(x^*) = x \rightarrow$

$s \Vdash \langle\langle \exists, x^*, \langle\langle P, x^*, T \rangle\rangle, T \rangle\rangle$

(P3b) $(\exists@x^*, f)\ s_@ \Vdash f[\langle\langle P, x^*, T \rangle\rangle] \wedge f(x^*) = x \rightarrow$

$s_@ \Vdash \langle\langle \exists@, x^*, \langle\langle P, x^*, T \rangle\rangle, T \rangle\rangle$

A situation in general makes an existential infon true if the generic infon in the scope of the quantifier can be anchored in

the bound variable to that situation (i.e. to an object present of the appropriate category, that object being a constituent part of the situation: $x \prec s$). Just so for real situations, their constituents, and [∃@, ∀@].

One could express this situation relative quantification also by using a *Generalized Quantifier*: $(\exists x \prec s)$, and so on. The antecedent in (P3) makes the restriction obvious for simple cases which concern infons *about* the situation *s*. In cases where some constituent of *s* plays a role in an infon involving some *other* situation (e.g. by spatio-temporal reference) the Generalized Quantifier has its uses. Example: in (the content of) "One of these bottles has been opened yesterday" the quantifier picks out a bottle in the current situation to state something about *it* in another situation the domain of which could differ in bottles. In uses of *Generalized Quantifiers* the restriction of the quantifier refers to a 'resource situation' s_1 and the clause to some other situation s_2, while they might be the same situation.

A truth-condition for existentially quantified infons (a precise version of the above principle) refers to anchors (and variations of anchors) like a truth-condition in the model theory of FOL refers to variable assignments. Expressed otherwise: an existential quantification *says* in effect (in a Fregean understanding of quantifiers as higher order predicates) that some relation can be instantiated by anchoring in a situation at hand. Similar for [∀].

One has to distinguish the logical structure *within* contents and claims made in an SF analysis (on the meta-level) about situations and contents, e.g.

$$(\exists x, f)\ s \Vdash f[\langle\langle P, x^*, T\rangle\rangle] \wedge f(x^*) = x$$

This asserts that some variable can be anchored in *s*, more specifically that *there is* a *P* in *s*. Logic principles are, obviously, stated on the meta-level.[8]

Truth-values present in infons can stand in for negation. The content of the sentence "Linda is not in Cologne" is the infon <<In, Linda, location: Cologne, F>>. We should have the principle:

(P4a) If α is a sentence with content <<R, x..., T>> for some relation *R* and arguments *x*..., then <<R, x..., F>> is the content of ¬α.

Situation are partial, so are (sets of) infons made true by them. If an infon using the truth-value T is not made true by a situation *s* one cannot conclude from this *alone* that using F in that infon will result in an infon made true by *s*, because in a bivalent SF setting one may need a totality claim, which grounds a negative fact then. The infon using F can, of course,

[8] This meta-level of talking could in a most comprehensive (paraconsistent) SF, which does not distinguish object- from meta-language, be expressed in infon-format as well. For ease of exposition of basic infon logic one might keep the levels apart. The issue of semantic closure might be dealt with later, in a more extensive treatment of self-reference and circularity, that §8 begins with.

follow from infons made true by *s*. Totality claims have to be explicitly added, supposedly as relative totality claims (i.e. concerning a totality of positive information, say $\Gamma_{\text{CharlesII,T}}$ about Charles II).[9]

Extensions of a situation making a totality claim true, make it true themselves.

Given this, some principles of *preservation of truth-making by situational extension* hold:

(P5a) For basic positive infons φ:

$$(\forall s_1, s_2)(s_1 \prec s_2 \supset (s_1 \Vdash \varphi \supset s_2 \Vdash \varphi))$$

(P5b) For existential positive infons φ:

$$(\forall s_1, s_2)(s_1 \prec s_2 \supset (s_1 \Vdash \varphi \supset s_2 \Vdash \varphi))$$

(P5) trivially holds by adding information or constituents. Negative infons may no longer be supported by adding facts. Universal infons can meet a counterinstance by situational extension. If one makes the bounded quantification explicit, like

$$i_1 = \langle\langle \forall, x^* \prec s_3, \langle\langle P, x^*, T\rangle\rangle, T\rangle\rangle$$

then $(\forall s_2)(s_3 \prec s_2 \supset s_2 \Vdash i_1)$. For explicitly restricted universal quantification *preservation of truth-making by situational extension* holds.

[9] Cf. §8 on using self-reference in stating a totality claim (in an infon).

If SF was extended by default rules, extension could require dropping some elements of logical closure by defaults (as exceptions may be added). Otherwise, one may define that a situation s_1 supports a defeasible conditional infon only if all situations s_2 such that $s_1 \prec s_2$ support it. This seems hardly useful as it requires total knowledge of world composition, and thus in effect substitutes worlds for situations. A better option will be a situational support for an (conditional) infon by situation s_1 and, maybe, detachment on it in s_1, and later revision of Γ_{s1} if exceptions or inconsistencies occur in $\Gamma_{s1} \cup \Gamma_{s2}$ for a situation s_2 such that $s_1 \prec s_2$ or $s_1 <_t s_2$. This option may instead of introducing a special default conditional combine ordinary detachment with a theory of Belief Revision (cf. Gärdenfors 1988, Tennant 2012, [cf. §9]), which also, seen from the perspective of later or more comprehensive situations, makes the consequence relation non-monotonic.

The logical framework in the current SF is intended to allow for a 4-valued IFL. Most principles, however, apply to a 2-valued SF as well. Controversies about N and B are side-issues within ST. SF reduced to using T and F suffices for the main topics of ST (like the main variations of information flow [in §§4. 5, 7]).

In the current SF setting truth-value N may be appropriate in case where the positive infon is *not* made true, and *neither* is an infon containing a directly contrasting relation (e.g. in pairs like Cold/Warm, Small/Great etc.).

In case an argument of a relation is filled by an entity of the wrong *semantic* category – not to be confused with the

ontological categories – the positive infon cannot be made true; the infon should use the truth-value F; <<Green, 7, T>> cannot be made true, <<Green, 7, F>> should be made true by all situations, because analytic. Some have argued for applying truth-value N to semantic category mistakes, but in the current SF truth-value N should only be applied to indeterminate cases of sentences with *vague* general terms and infons which contain the corresponding vague (disjunctively defined) relations. In case an argument of a relation is filled by an entity of the wrong *ontological* category the infon may not be well-formed at all (like the corresponding sentence being gibberish). “is Green kisses true” is not a sentence, but gibberish, correspondingly <<Kiss, Green, T, now*, T>> is not a well-formed infon.

Truth-value F standing in for negation has been an original element of ST, but given that there are negation functions, expressed by [¬] and [~], these should – on pains of inexpressibility of some theoretical claims – be present in infons as well. Thus, there should be an infon <<¬, <<R*, x*...>>>>, and, and given the presence of [~] in SF, an infon <<~, <<R*, x*...>>>>.

Using prefix notation with [¬] to get <<¬ <<R*, x*...>>>> and infix notation for logical functions with two arguments the mirror image of PC is completed: logical functions appear in infons at the same places logical operators and connectives appear in sentences. Again, in infons we have functions, not symbols.

There are principles relating these *kinds of negative infons* with negations to the other negative infons with truth-value F and, maybe, truth-value N, which depend, of course, on SF being 2-valued or not. Given the current 4-valued SF one has:

(P4c$_1$) $s \Vdash \langle\langle \neg, \langle\langle P^*, a^* \rangle\rangle \rangle\rangle \longleftrightarrow$

$s \Vdash \langle\langle P^*, a^*, F \rangle\rangle \vee s \Vdash \langle\langle P^*, a^*, N \rangle\rangle$

(P4c$_2$) $s \Vdash \langle\langle \sim, \langle\langle P^*, a^* \rangle\rangle \rangle\rangle \longleftrightarrow$

$s \Vdash \langle\langle P^*, a^*, F \rangle\rangle$

(P4c$_3$) $s \Vdash \langle\langle \sim, \langle\langle P^*, a^* \rangle\rangle, N \rangle\rangle \longleftrightarrow$

$s \Vdash \langle\langle P^*, a^*, N \rangle\rangle$

(P4c$_4$) $s \Vdash \langle\langle \neg, \langle\langle P^*, a^* \rangle\rangle, B \rangle\rangle \longleftrightarrow$

$s \Vdash \langle\langle P^*, a^*, B \rangle\rangle$

and so on.

All that has been said about negative infons being made true by a situation applies, of course, to negative infons in this format as well. Given this use of negations and the option to include [$\Vdash$] and semantic predicates in infons, truth-value objects could be dropped; SF keeps them for convenience, and – for once – for continuity to traditional ST.

Still, however, situations are partial:

(Partiality 1) $s \nVdash \langle\langle P^*, a^* \rangle\rangle \nrightarrow$

$s \Vdash \langle\langle \neg, \langle\langle P^*, a^* \rangle\rangle \rangle\rangle \vee s \Vdash \langle\langle P^*, a^*, F \rangle\rangle$

and even more importantly:

(Partiality 2) $s \nVdash \langle\langle \neg, \langle\langle P^*, a^* \rangle\rangle \rangle\rangle \nrightarrow$

$s \Vdash \langle\langle P^*, a^* \rangle\rangle$

Absent claims on totality [as discussed above] a situation not making an infon true does not entail that it makes the corresponding negative infon true. Not for all absent support of a negative infon the situation contains the corresponding positive fact.

Partiality allows an easy and natural modelling of information gain and situational extension (by $s_1 \prec s_2$ and persistence) without permanently revising the negative informational content contained in a situation.

Situations, infons, the truth-making relation, and the consequence relation between infons along the lines indicated build *algebraic structures* which are not Boolean even in a two-valued SF (by partiality of situations and negation in infons present by truth-value F).

In contrast, a real situation supports an infon or it does not:

(P6a) $(\forall s \prec w_{@})(s \Vdash i_1 \vee \neg s \Vdash i_1))$

As for a real situation *s* [$s \Vdash i_1$] is the *proposition* that i_1 obtains [cf. §3], propositions are true or they are not. Propositions, thereby, form a Boolean algebra. (P1) and (P2), for instance, are principles of this algebra. Propositional contents of statements form a Boolean algebra mirroring the Boolean algebra of statements and correlated eternal sentences (i.e. statement logic, a.k.a. PC). SF, thus, *integrates* Propositional

Logic in the narrow sense (i.e. as the logic of propositions). Logical principles covering infons supplement the perspective of a theory of information flow.

In a two-valued SF one may introduce top <<⊤>> and bottom <<⊥>> infons. Every situation makes <<⊤>> true and none <<⊥>>. Given (P1) and (P2) infons can form then a *distributive lattice*.

Given <<⊥>> two infons i_1, i_2 are *incompatible* if $\{i_1, i_2\} \vDash$ <<⊥>>. The two infons are then complements of each other, which initiates constraints:

(P6b) $S_1 = [s \mid s \Vdash i_1] \wedge S_2 = [s \mid \neg\, s \Vdash i_2] \rightarrow$

$(S_1 \Rightarrow S_2)$

For any pair of infons $<i_1, i_2>$ such that $i_1 \nvDash i_2$ there is a situation which distinguishes between them in truth-making:

(P6b) $(\forall i_1, i_2)(\, i_1 \nvDash i_2 \rightarrow (\exists s)(s \Vdash i_1 \wedge \neg s \Vdash i_2))$

Given the set of infons $\Gamma_s = \{\, \varphi \mid s \Vdash \varphi\}$, which contains the infons distributively, one can consider the logical meet of Γ_s. SF containing some consequence relation [⊨] defined for infons, the closure as (distributive) set should already be included: $\{\, \varphi \mid \Gamma_s \vDash \varphi\} \subseteq \Gamma_s$. A situation makes a set of infons true if it makes each member of the set true, and situations are closed by **IFL**. Whether the meet of Γ_s can be represented by a single formula is questionable: SF does not support infinite conjunctions for sentences, because no (earthly) cognitive

agent can represent them, but an infinite infon conjunction is not excluded by this – what could it be good for?

(P2) shows that situations support adding *irrelevant* disjuncts to obtaining infons (i.e. disjuncts about any entities not present in the situation at all). For any contingent disjunctive infon a truth-making situation makes at least one disjunct true.

(P4) uses Boolean negation [¬]. Concerning truth-value N in the presence of a strong predicate negation [~] correspondence conditions will be more difficult:

(P4b) If α is a sentence with content $<<R_1$, x..., T>> for some relation R_1 and arguments *x*..., then $<<R_2$, x..., T>> is the content of $\sim\alpha$, where R_2 is the contrast relation to R_1.

A full justification of an SF with truth-value N will have to introduce the concept of ‘contrast relation’. The contrast in question mirrors the contrast expressed in natural languages often by “in-“ or “un-“ (e.g. “competent”/”incompetent”, “dressed”/”undressed”), where some person may be *neither* competent nor incompetent:

<<Competent, Fred, N>>

falling in the indeterminate range, but somebody else certainly is:

<<∧, <<Competent, Luke, F>>,

<<Incompetent, Luke, T>>, T>>

as the presence of a range of indeterminacy, of course, does not exclude the presence of clear cases, otherwise vague terms would have no proper use.

Modal operators as known from modal logics correspond to modal functions, which may occur in infons. Not all of them may have a natural employment in infons, but entailments have: $<< \Box, << \supset, i_1, i_2>>>>$ contains the information that i_1 obtaining excludes i_2 not obtaining for *all* situations which make $<< \supset, i_1, i_2>>$ true, i.e. that one will never meet a situation making i_1 true and i_2 not.

Situations support infons with modal content given accessibility relations between situations, as might be (i) either derived from the accessibility relations between worlds the situations are part of, or (ii) directly defined for situation by recourse to the constraints linking them.

In case (i) two situations covering some content φ are modal alternatives to each other *via* the worlds they are part of being alternatives to each other. Truth-conditions of standard modal logics (like S4 or S5) provide the blueprint for supporting modal infons, with principles like:

$$s \Vdash \varphi \wedge s \prec w \wedge (\forall w^*)(\text{Accessible}(w, w^*) \supset (\exists s^* \prec w^*)\, s^* \Vdash \varphi) \rightarrow s \Vdash << \Box, \varphi>>$$

In case (ii), accessibility by constraints is reflexive, because the situation supports the constraints connecting it to other situations, and transitive by the *Xerox Principle*. Because constraints are not just unidirectional causal links, there should

be for any forward reasoning/information flow constraint a backward reasoning/information flow constraint going in the other direction of the original constraints, thus accessibility by constraints is symmetric. This *Trias* of accessibility conditions gives S5 like modalities. The IFL conditional itself and even negation for situations as partial might be given a detailed modal semantics of the type used in Relevant Logic, with constraints as *channels of accessibility* [cf. §8].

So, both options (i) and (ii) result in support conditions for the infon $<< \Box, \varphi>>$ which resemble truth-conditions in S5. In case (ii) support conditions for $<< \Box, \varphi>>$ are secondary, once accessibility and support have been defined for the conditional.

Whether cognitive agents know or are attuned to all the constraints depends on them (i.e. even if modal content is available objectively need not ensure its extraction by cognitive agents).

Infons have closure conditions. Infons are generally *closed* (i) under *infon logical principles* covering them, and infons obtaining in a situation are *closed* (ii) under *constraints* of that situation. For an infon φ and the total information Λ_s of a situation *s* (including all the constraints covering *s*) with $s \Vdash \varphi$,

$$\Gamma_\varphi = \{ \phi \mid \Lambda_s \cup \varphi \vDash \phi \}$$

is the closure of φ in *s*.

Information states of information processors in a situation *s* are *closed* under (i) the recursive conditions on infon complexity (like conjunctive closure analogous to (P1)) and (ii) the closure conditions of the infons they are informed about in *s*, i.e. the total union $\cup\Gamma_\varphi$ for all these infons φ, i.e. <<INFORMED, a*, ϕ>> for any ϕ where $\cup\Gamma_\varphi \vDash \phi$. The amount of information an information processor *objectively has* in a situation – attested from a 3^{rd} person perspective – will be enormous, most of it of no interest. In case the information processor is a cognitive system most of the information will not even be dispositionally available subjectively, because *subjective* availability requires knowledge of Λ_s and logical perfection.

Example: Let *NutritiousObject* be the type of objects which are nutritious, agent* to be anchored to a squirrel (squirrel$_{17c}$) in a situation *s* where some individual nut (nut$_{3c}$) is in a bowl (bowl$_{5c}$). We have the general constraint that infons which are the content of a state of perception by any agent are infons the agent is informed about, and a general constraint that nuts are nutritious. Then we may presume:

Fact: s⊩<<Perceive, agent*, <<In, bowl$_{5c}$, nut$_{3c}$>>>>

C_1 = [s* | s*⊩<<Perceive, x*, i*>>] ⇒

[s* | s*⊩<<INFORMED, x*, i*>>]

(Remember that identical variables in different infons in constraints have to anchored uniformly. Use of [s*] in both types entails that the situations of perceiving and being informed are identical.)

So, by the first constraint and

s: [s* | s*⊩<<Perceive, x*, i*>>]

with anchoring we get:

s⊩<<INFORMED, agent*, <<In, bowl$_{5c}$, nut$_{3c}$>>>>

An instance of the general constraint that nuts are nutritious (true in all situations) is:

s⊩<<nut$_{3c}$: NutritiousObject>>

So, by the second constraint:

s⊩ { <<INFORMED, agent*, <<In, bowl$_{5c}$, b*>>>>,

<<INFORMED, agent*, <<Nutritious, b*>>>> }

So, by logical closure and bringing in that squirrel of the situation we get:

s⊩ <<INFORMED, squirrel$_{17c}$, <<∃, b*, <<∧, <<In, bowl$_{5c}$, b*>>, <<Nutritious, b*>>>>>>>>

So, if the squirrel perceives in the situation that some nut is in a bowl, the squirrel by this *has* the information of something nutritious being in the bowl, maybe by being attuned to the constraint that nuts are nutritious, but certainly not by having a theory of reliable perception and existential generalization.

From the perspective of objective information flow the agent is *informed* about everything which is implied by the information the agent has – given the agent's representational resources – or which is in the transitive closure of the operative constraints. This massive idealization, even if relativized to the agent's representational resources, assumes that the agent's cognition works by some closure principle, or at least allows dispositionally to proceed to even further information.

In the case of the squirrel one has to be cautious how far to carry such information extraction, for instance: as IFL *might* endorse *verum ex quodlibet sequitur* something has to be done about the ‘paradoxes of material implication’, otherwise the squirrel having information on too many logical truths.

Logical closure can be expressed in ST/SF at the level above partial situations in its generality by [$\vDash$], using the concept ‘consequence’ for infons *and* sentences, but could also be expressed as a necessary conditional infon made true by $w_{@}$.

Although we have used [$\vDash$] for infons as well, consequence for infons, however, *cannot be identical* to consequence for sentences (i.e. closure under SOL or some extension of it), as infons are restrictive in the content they contain, as argued above. So, in discussions where the distinction is important we have to distinguish between [$\vDash_I$] for infons and, say, [$\vDash_{SOL}$] for sentences.

Let Λ be the set of all (relevant) constraints including infon logical constraints, then this closure principle should hold, if [$\vDash_I$] is consequence for infons:

(P7a) $\Lambda \cup \{\varphi\} \vDash_I \phi \rightarrow$

$s \Vdash \langle\langle \text{INFORMED}, a^*, \varphi \rangle\rangle \supset$

$s \Vdash \langle\langle \text{INFORMED}, a^*, \phi \rangle\rangle$

(P7b) $w_{@} \Vdash \langle\langle \Box, \langle\langle \supset, \Lambda \cup \{\varphi\}, \phi \rangle\rangle\rangle\rangle \rightarrow$

$s \Vdash \langle\langle \text{INFORMED}, a^*, \varphi \rangle\rangle \supset$

$s \Vdash \langle\langle \text{INFORMED}, a^*, \phi \rangle\rangle$

Agents have the information *entailed* by the original information they extracted, but even cognitive agents aware of constraints may not *know* that they have this information, because knowledge is not closed under objective entailment. The consequence relation in (P7), and entailment infons, however, have to be restricted to exclude, crucially, *verum ex quodlibet*.

Inference by cognitive agents *using* representations of constraints is, thus, a special case of information flow by closure of infons. Inference by *using* linguistic representations (including inference in natural and formal languages) is even more special (as subcase of representational inference), but presumably less restrictive in its closure conditions.

Situations have temporal extension. So, principles of an interval-based temporal logic (cf. van Benthem 1983) can be integrated into SF. Or more general: situations stand in temporal relations of an order expressed with [$<_t$] and [$=_t$], which allows to lay down principles of a model of time in their terms, and to introduce the usual modal temporal operators for past [**P**] and future [**F**]. For a model in which time is tree-like with a single past, but several possible future paths, and beginningless and endless, principles are (cf. Harada 1993): irreflexivity and transitivity of [$<_t$], and:

(No Start No End)

$(\forall s^*_1)(\exists s^*_2, s^*_3)(s^*_1 <_t s^*_2 \wedge s^*_3 <_t s^*_1)$

(Linear Past)

$(\forall s^*_1, s^*_2, s^*_3)(s^*_2 <_t s^*_1 \wedge s^*_3 <_t s^*_1 \supset$

$s^*_3 <_t s^*_2 \vee s^*_2 <_t s^*_3 \vee s^*_3 =_t s^*_2)$

(Directedness)

$(\forall s^*_1, s^*_2)(\exists s^*_3)(s^*_3 <_t s^*_1 \wedge s^*_3 <_t s^*_2)$

and so on...

An infon φ about the past (containing as main function past shifting, expressed by [**P**], applied to infon ϕ) will be supported by a situation s_1 if there exists s_2 with $s_2 <_t s_1$ which supports ϕ. In contrast to the closed past, the future is open in such an indeterministic time logic. So, an infon φ about the past (containing as main function future shifting, expressed by [**F**], applied to infon ϕ) will be supported by a situation s_1 if all s* with $s_1 <_t s^*$ support ϕ: only certain claims about the future are true already in s_1 – and so on...

Further on, (at least) real situations can be parts of other real situation, so principles of mereology (e.g. principles of the parthood and overlapping relations, cf. Ridder 2002) can be integrated into SF. For instance, not only the relation of parthood [$\prec$] has its own principles (like transitivity), and interrelations to the relation of overlapping [$\bigcirc$] (e.g. situations which overlap have a common part situation):

(Trans $\prec$)

$(\forall s^*_1, s^*_2, s^*_3)(s^*_1 \prec s^*_2 \wedge s^*_2 \prec s^*_3 \supset s^*_1 \prec s^*_3)$

($\bigcirc/\prec$)

$(\forall s^*_1, s^*_2)(s^*_2 \bigcirc s^*_1 \supset (\exists s^*_3)(s^*_3 \prec s^*_1 \wedge s^*_3 \prec s^*_2))$

There should also be the principle of *general fusion* of co-temporal situations, even if the two situations fused are spatially distracted:

(Fusion 1)

$(\forall s^*_1, s^*_2)(s^*_2 =_t s^*_1 \supset (\exists s^*_3)(s^*_1 \prec s^*_3 \wedge s^*_2 \prec s^*_3))$

For any two co-temporal situations there will always be a third both are part of, which does not exclude that $s^*_2 = s^*_3$ or $s^*_1 = s^*_3$. As this principle can be iteratively applied, there will be a maximal fusion, a maximal situation – the world at that time. If s^*_2 and s^*_1 are *compatible* [cf. §8] the fusion supports every infon one of them supports:

(Fusion 2)

$(\forall s^*_1, s^*_2, s^*_3)(s^*_2 =_t s^*_1 \wedge s^*_1 \prec s^*_3 \wedge s^*_2 \prec s^*_3 \supset$

$(\mathrm{COMP}(s^*_1, s^*_2) \supset s^*_3 \Vdash \Gamma_{s^*1} \cup \Gamma_{s^*2}))$

In case they are not compatible some negative infons supported by respectively one of them have to retracted; as said above, preservation of support does not hold for negative infons. A full theory of fusion conditions (including uniqueness of the fusion) will be advanced situation mereology. Extensional uniqueness requires at least:

(Fusion 3)

$$(\forall s^*_1, s^*_2)(s^*_2 =_t s^*_1 \supset (\exists s^*_3)(s^*_1 \prec s^*_3 \wedge s^*_2 \prec s^*_3 \wedge (\forall s^*_4)(s^*_4 \prec s^*_3 \supset s^*_4 \prec s^*_1 \vee s^*_4 \prec s^*_2 \vee (s^*_4 \bigcirc s^*_1 \wedge s^*_4 \bigcirc s^*_2 \wedge \neg(\exists s^*_5)(s^*_5 \prec s^*_4 \wedge \neg s^*_5 \bigcirc s^*_1 \wedge \neg s^*_5 \bigcirc s^*_2)))))$$

The co-temporal fusion of s_1 and s_2 is unique in its minimality: any part of it if not part of one of s_1 or s_2 overlaps them, and also has no parts itself outside them.

Fusion principles for situations at different times account for (possibly fragmented) histories. Once again, one will end up at the world (history). If one assumes that real situations exist, one has to admit that the real world as their fusion exists.

(Barwise & Etchemendy 1990) and others have extended the logical component of ST. (Devlin 1991) coined the terms 'infon' and 'infon logic'. An early logical perspective on a framework based on situations can be found in (Fenstad et al. 1987). A situation-based semantics also has been employed in some quarters of Relevant Logic (cf. Mares 2004), which will be taken up in §8. Turning to Relevant Logic as basis of infon logic seems a major change from ST tradition, which, however, always stressed partiality and explored stronger conditionals than material implication, at least in constraints, but presumably beyond that.

§7 Basic Analysis of Attitudes and Action

Infons are objective contents. In case of attitudes infons are *de re* contents. In case ST wants to ascribe *de dicto* content either representations have to be explicitly included in infons or infons are used which contain what the agent *really* believes, fears ...

For agents which have no propositional attitudes objective content ascription use infons and the relation INFORMED: <<informed, squirrel, <<In, bowl, nuts>>>>. A squirrel can have or can have extracted the information nuts being in the bowl without having a propositional attitude with the content *that* nuts are in the bowl. Squirrels have no propositional attitudes (in the proper narrow sense) at all, but they are cognitive agents, although we cannot identify the representations *they* use. SF can describe them as being informed about features of a situation and extracting information there from by constraints they are attuned to.

In SF 'belief worlds' in the sense of modal Epistemic Logic are those possible worlds which *support* a set of infons compatible with the agent's beliefs. (Remember: worlds are not sets.)

Although ST models are semantics and do not focus *tout court* on the representations used by agents, this in itself does not exclude modelling the *subjective* attitudes and beliefs of an agent. Subjective attitudes can be described from a 3rd person perspective by referring to exactly those objective contents the agent has the attitudes to. Sometimes this may involve reference to the representations the agent has for some entities. The subjective character of attitudes is obvious in those cases where these attitudes are misguided.

Example: Say, Fred believes that there *are* unicorns (i.e. in the real world). The real world, however, isn't so. Fred, therefore, cannot – in broad *or* narrow scope – believe *of* the real world that it contains unicorns. Fred believes, say in situation s_5, a merely possible world *w* which contains unicorns to be real:

$s_5 \Vdash \Gamma$

Γ= {<<NON@, w*, T>>,

<<BELIEVE, Fred, <<@, w*, T>>, T>>

<<BELIEVE, Fred, w* ⊩ <<∃, x*, <<Unicorn, x*, T >>, T>>, T>>}

One may existentially quantify w* or anchor it to Fred's prioritized belief world (or just one of Fred's belief worlds, all of which support the existence of unicorns). In ordinary belief reports beliefs about possible worlds seldom occur, so that the description can be simplified:

<<BELIEVE, Fred, <<∃, x*, <<Unicorn, x*, T >>, T>> T>>

Fred (still) believes something *of* the property *Unicorn* (namely that it is instantiated). Infons are the contents of attitudes. Attitudes are relations to contents, which relations play a specific functional role in the agent's cognition. Note that the [∃] in w* and the simplified belief report quantifies over

possibilia (like the unicorn), not over really existing individuals.

So, Fred's belief that there *really are* unicorn can be described in SF notation in 3rd person perspective as:

<<BELIEVE, Fred, <<∃, x*, <<∧, <<@, x*>>,

<<Unicorn, x*>>>>>>>>

[The truth-value T has been omitted by notational convention. §6 explains the use of conjunction in infons.]

Fred believes *de dicto* that there is something existing that it is a unicorn. That may be true of Fred, as there *is* a false sentence with that content, whereas the *de re* report that Fred believes of something existing that it is a unicorn is false:

<<∃, x*, <<∧, <<@, x*>>,

<<BELIEVE, Fred, <<Unicorn, x*>>>>>>>>>>

Combining [∃] and [@] gives quantification existential impact in the narrow sense of talking of entities which are parts of reality.

Propositions of the form $s \Vdash \varphi$ (that some infon obtains) and type assignments of the form of [$a_3 : O_8$] (classifying entities) are also contents of beliefs:

<<Believe, Linda, $s \Vdash \varphi$, T>>,

<<Believe, Linda, $a_3 : O_8$, T>>

(Believing a proposition *means* believing it to be true, thus adding [T] again in the belief *content* of such a belief describing infon would be pleonastic. The belief *describing* infon, of course, claims it to be true that somebody has some belief.)

According to the *Representational Theory of Mind* the contents are represented in some medium, but for many analytic purposes ST can concentrate on the objective content itself.

De dicto attitude reports may refer to representations used by an agent. Fred may have different representations for Tolkien: ®$_1$Tolkien, ®$_2$Tolkien, based supposedly on definite description or collateral beliefs. It may happen then that Fred likes the one author, but not the other. Objectively Fred has an inconsistent belief:

s ⊩<<BELIEVE, Fred, <<∧, <<Like, Tolkien>>,

<<Like, Tolkien, F>>>>>>

The inconsistency can be resolved as this can be described in a *de dicto* report referring to representations as *relata* of Fred's beliefs, the objective content of the infon associated with a *guise* in which it is processed:

<<Like, Fred, ®$_1$Tolkien>>

<<Like, Fred, ®$_2$Tolkien, F>>

|| ®$_1$Tolkien || = || ®$_2$Tolkien || = Tolkien.

Under the representation (in the guise) ®$_1$Tolkien Fred does like Tolkien, under the representation (in the guise) ®$_2$Tolkien he does not. *De re* Fred's beliefs are inconsistent, but *de*

dicto they are not. Fred may lack knowledge about Tolkien, but is not confused.

Representations are real parts of a cognitive system, infons containing them, thus, do not contain problematic ontological posits, especially an infon containing them still states an objective relation between existents. (Again, the infons are still not *parts* of the cognitive systems, but the *contents* of representations which are parts of the cognitive system.)

In this way intensional phenomena (like 'puzzles of belief') can be explained. The representation indicator [®] is opaque: the analyst need not know the representation or representational format used by the agent. This way an analysis of this kind could even be applied to animals and technical systems, if there was any reason to depart from an ascription of processing objective (non-intensional) informational content. ST can endorse a *Representational Theory of Mind*.

SF may spell out conditions to ascribe kinds of mental attitudes. For instance, one may define a *reliable* belief as a form of *knowledge*. Suppose:

s_1⊩<<Ring, 🔔>>

s_2⊩<<BELIEVE, Linda, <<Ring, 🔔, s_1>>>>

s_2⊩<<CAUSE, s_1, s_2>>

then we might be inclined to see Linda's belief as a kind of reliable perceptual knowledge:

s_2⊩<<KNOW, Linda, <<Ring, 🔔, s_1>>>>

Note that s_2 may be small enough to contain not much else besides Linda; epistemological casuistic may require to add a lot of conditions to exclude deviant causal connections. The content of Linda's perceptual knowledge is *de re* content. Perceptual attitudes have a *de re* and a *de dicto* version (e.g. seeing an object *vs.* seeing that something is the case). In

$s_3 \Vdash$ <<hear, 🐈 $_{\text{George}}$, 🔔, now*>>

George hears the individual in situation s3, George being a cat. Thus, we can – as we obviously do – share de re content with animals. The cat 🐈 $_{\text{George}}$, lacking at least beliefs about technology, certainly does not possess the concept 'doorbell', but how George represents plays no role in the report. (Pictograms highlight that one individual 🔔 may be represented by agents employing quite different means.) We might doubt that cats have propositional attitudes. So, the report above may be appropriate, whereas

$s_3 \Vdash$ <<hear, 🐈 $_{\text{George}}$, $s_3 \Vdash f$[<<Ring, 🔔, here*, now*, T>>] >>

might be inappropriate in reporting the *propositional* attitude of hearing *that* right now in the situation the doorbell rings. (The roles [here*] and [now*] will be anchored by *f* to s_3, if need be to a more specific location and time or sub-situation for spatio-temporal extended situations.)

Cognitive agents which have no propositional attitudes like BELIEF (many animals, for instance) have *object-oriented attitudes*. The infon <<See, cat, squirrel>> reports that some cat

sees some squirrel (both salient in some situation), not that the cat sees *that there is* some squirrel. Even the infon <<See, cat, <<In, tree, squirrel>>>> expresses an object-oriented attitude between the cat and some fact. Facts as constituents of real situations can be objects of attitudes without these attitudes being propositional attitudes. All these reports identify the content of the attitude from a 3rd person perspective of the human reporter. Co-referential names of the object can be substituted for each other. A theory in Cognitive Ethology may try to identify the conceptual resources a kind of animal possesses, and in this case the report will not allow substitution with expression that for humans are co-referential to the ones used. <<See, cat, <<In, thickBird, opening>>>> may express that the cat has some concepts to distinguish thick birds (like doves) from small birds (like sparrows) – or even finer distinctions for types of birds – but <<See, cat, <<In, dove, atticWindow>>>> reports from a human perspective, which not only knows about species, but also of artificial housing with kinds of openings.

The focus in ST on external content may in this way helpful for a better description of non-human information processors or cognitive agents in Cognitive Science. Object-oriented attitudes allow taking a *cognitive stance* towards agents, which is not the *intentional stance* (in the typical narrow sense of ascribing propositional attitudes – often in an anthropomorphic manner).

Persons also have attitudes of the object-oriented kind, for instance: <<Trust, Fred, Linda>>, <<Fear, Fred, Dracula>> etc. Reports on these attitudes are typically *de re*, and, thus, they allow quantifying-in, with or without actuality impact:

(∃@a)<<Trust, Fred, a>>, because Linda actually exists [@(Linda)], but Dracula does not: (∃a)<<Fred, Fred, a>>.

Not all these reports are *de re*, the exception being those cases the proper report of which needs to mention some representation the agent employs, for instance, <<Fear, Fred, ®nextDoorNeighbour>> and <<Trust, Fred, ®carMechanic>>: Fred trusts his car mechanic, although the mechanic is his very neighbour, what Fred has not recognized yet. Reports employing representations do not allow quantifying-in as the representations can be completely empty (i.e. not even refer to *possibilia*).[10]

Actions are, obviously, situated. Action explanations refer to beliefs and desires. Actions are intentional body movements (i.e. could be taken as individuals or as *events*, i.e. as a type of situation [cf. §3]). Body movements, and therefore intentional body movements, include abstaining from movement. Actions are explained as preferred to alternative courses of

[10] Even in a Positive Free Semantics not every singular term needs to refer to a possible object. This way a Positive Free Semantics permits that an agent uses a representation, but the conception it aims to express is too incoherent or confused to associate even a possible object with it. Basic (not attitude reporting) infons containing such a term are even *not well-formed*, as they miss an argument place being filled by an entity. Sentences expressing them may sound well-formed syntactically, but are semantic gibberish. A Negative Free Semantics agrees with this, as in it even all basic sentences with non-referring singular terms are false.

action. An alternative course of actions could be to do nothing.

Of course, action explanations are, because of the holism of the mental, *defeasible*, and irreducible to explanations in physics or even biology.

Action explanations may paradigmatically proceed this way:

Question: Why does some agent agent* enact body movement a* (physical basis of an action, $a^* \in$ Events) in situation *s*?

Explanation:

(i) $S_1 = [s \mid s \Vdash <<\wedge, <<\text{BodyMovement}, a^*>>, <<a^*: H_1>>]$. S_1 is the type of situations in which a body movement of a certain type H_1 takes place.

(ii) $S_2 = [s \mid s \Vdash i_{3c}]$. S_2 is the type of situations containing a certain fact (corresponding to i_{3c} obtaining).

(iii) $\Gamma = \{s_1 : S_1 \wedge s_2 : S_2 \wedge s_1 <_t s_2\}$. This is the condition that a situation of type S_1 precedes a situation of type S_2 in time. Γ may contain further conditions, depending on the type of body movement.

(iv) $C_1 = S_1 \wedge \Gamma \Rightarrow S_2$. This is the constraint that under certain conditions a body movement of type H_1 is followed by i_{3c} obtaining.

(v) $s \Vdash <<\text{WANT}, agent^*, i_{3c}>>$. The agent wants i_{3c} to obtain (i_{3c} is a goal state of the agent).

(vi) $s \Vdash \langle\langle \text{BELIEVE}, \text{agent*}, \Lambda_s \rangle\rangle$ where $\Lambda_s = \{\langle\langle \text{BodyMovement}, a^* \rangle\rangle, \langle\langle a^*: H_1 \rangle\rangle, \langle\langle \text{Feasible, action: } a^*, \text{agent*, situation: } s \rangle\rangle, C_1\}$. The agent believes that it is feasible to attain the wanted state by enacting the body movement a* in *s*, reasoning along constraint C_1.

(vii) $\neg\exists\Lambda(\Lambda = \{\langle\langle \text{BodyMovement}, a_2^* \rangle\rangle, \langle\langle a_2^*: H_2 \rangle\rangle, \langle\langle \text{Feasible, action: } a_2^*, \text{agent*, situation: } s \rangle\rangle, C_2\} \wedge s \Vdash \langle\langle \text{BELIEVE}, \text{agent*}, \Lambda \rangle\rangle)$, where constraint C_2 is a constraint linking body movement a_2^* with achieving i_{4c} such that $s \Vdash \langle\langle \text{Prefer}, \text{agent*}, i_{4c}, i_{3c} \rangle\rangle$. The agent does not believe that there is another body movement feasible in *s* as well which results in a situation in which something preferable to i_{3c} obtains.

This, certainly, simplifies extensively (e.g. in the specification of the background conditions for some body movement to have the desired effect), but outlines the basic explanatory idea. In this explanation only *de re* content occurs. *How* the agent represents the situation and the options plays no role.

Intentional explanations are required for persons. An explanation of this kind – taking the 'intentional stance' – could explain the moves of a vacuum robot, granted an extension of the ascription of the attitudes to technical devices – a proper theory should have a special vocabulary here (like "register", "pursue" ... [cf. Bremer 2026a on this conceptual issue in Cognitive Ethology]).

The example also illustrates that attitudes are always situated. Parameters are anchored to elements of the situation (the same

indexical content being *efficiently* applicable in different situations).[11]

It has been stressed over and over that infons are not sentences, and the use of pictograms underlines that infons contain the entities involved in such objective content. This means, on the other hand, that cognitive agents *do not have infons in their mind*, their head, or anywhere else. Cognitive agents process representations, inasmuch as their cognitive processes are computational, *Fodor's Principle* ("No Computation without Representation") applies. The inner 'workings' of a cognitive agent, even those of a mere information processor cannot be modelled by infons and their relations. Infons can be part of a *semantic account* what content is processed by agents, and thus be part of *intentional explanations* of their actions. ST models of agents, thus, are semantic models which abstract from the representational systems of the agents. Such a model may describe infons in terms of the conceptual scheme of an agent, still these concepts are expressed from a 3rd person perspective, not in terms of the representations used by the agent, and even if such representations are

[11] §§2 and 3 exhibited the reliance of SF on a promiscuous ontology of *possibilia*. Typically, they are needed in attitude descriptions (like fearing Dracula or searching for the Holy Grail etc.). One ontological reduction program replaces such references to *possibilia* by mentioning the actual representations used in the attitudes. Of course, "®Dracula" in SF still presupposes the possible object, unless some dummy object for failing reference is part of the semantics, like in the classical account of definite descriptions or in some Free Logics, cf. Lambert 1991.

explicitly noted in an infon of meta-representational character, the framing SF-format explains from a 3rd person perspective. ST models, thus, seem far removed from computational models. Situation Theory and Situation Semantics are just that: semantics and ontology, not syntax. They explain which *information* an agent objectively has or extracts in situations, but not *how* this is done at a procedural level [cf. §9].

Events (being a sub-type of situations) are causes and effects. Being situations events stand in temporal and spatial relations. An event e_1 *causes* an event e_2 if and only if it is of a type such that a covering law (a type of constraint) has it effect an event of the type e_2 exemplifies, and because the law covers the causal link, one can also infer from the effect to the cause. So, a first *extensional* definition of [<<CAUSE, e_1, e_2>>] will combine these two conditions (cf. Davidson 1967).

Expressed in formal language format:

(CAUSE 1)

$$(\forall @e_1)(e_1{:}T_1 \supset (\exists @!e_2)(e_2{:}T_2 \wedge \mathrm{CAUSE}(e_1, e_2) \wedge e_1 <_t e_2)) \wedge (\forall @e_2)(e_2{:}T_2 \supset (\exists @!e_1)(e_1{:}\ T_1 \wedge \mathrm{CAUSE}(e_1, e_2) \wedge e_1 <_t e_2))$$

Then one may add postulates which characterize 'CAUSE', for instance one may require that causes are (locally) minimal:

(CAUSE 2)

$$(\forall @e_1, e_2)(\mathrm{CAUSE}(e_1, e_2) \supset \neg(\exists @!e_3)(\mathrm{CAUSE}(e_3, e_2) \wedge e_3 \prec e_1)$$

Further principles may capture the concept 'cause' of our *manifest image* of unfolding events and actions.

Expressing natural law statements in SF, in contrast, as structural patterns between temporal pre- and post-conditions, will not involve [CAUSE], since the concept does not occur in scientific law statements, but may involve either a stronger (non-material) conditional, which may be the type of conditional in infons anyway [cf. §8], or a theory of constraints in which some are more central than others – similar to a Humean theory of natural laws, which identifies them among empirical regularities by their centrality (e.g. in allowing to infer supervenient regularities). ST should be extended – some time – by a systematic theory of constraint types and their interrelations.

Given individuals, events, and attitudes (like intentions) one can regain widely accepted definitions of a theory of action:

(i) 'action': an intentional body-movement (i.e. some *event* e_1 caused by an immediately preceding intention, i.e. *another event* e_2); given (i):

(ii) 'doing something': an individual a_1 by having a corresponding intention causing an action e_1 in a situation s_1, while e_1 need not happen in s_1 by covering lawlike constraints C_i, a_1 'could have done otherwise'; given (ii):

(iii) 'refraining from something': an individual a_1 not doing action e_1 in situation s_1, while a_1 could do e_1 in s_1;

(iv) 'preventing something': an individual a_1 doing action e_1 in s_1 which results in a situation s_2 which by some conditioning infon of its situation type is incompatible with the conditioning infon of the situation type to be prevented [cf. §6],

(v) 'agent causation': an individual (of type [Person]) a_1 doing something e_1 which causes something else e_2 (the causal chain starting from a *person* a_1).

Like understanding a meaningful sentence requires common knowledge of the theory of meaning of the language of the utterance between speaker and audience [cf. §5], coordinated collective action requires common knowledge of the social norms operative in a context (i.e. a situation type). Like meaning works by constraints between situations of utterance and described situations, social norms work by constraints which relate antecedent conditions to a norm (say, what ought to be done) operative in a situation of the antecedent type or another situation linked to it by the conditions of the constraint. Such constraints are the content of conditional norm statements.

Conditional norm statements and their operators have been analyzed in Deontic Logic (cf. Åqvist 1987), which can be translated into SF.

Example: Consider the norm "Promises are/ought to be kept".

$$S_1 = [s \mid s \Vdash \{\langle\langle \text{Action}, a^*_1 \rangle\rangle, \langle\langle \text{Promises}, \text{speaker}^*, \text{audience}^*, \langle\langle \text{Do}, \text{speaker}^*, a^*_1 \rangle\rangle\rangle\rangle\}]$$

$$S_2 = [s \mid s \Vdash \{\langle\langle \text{OUGHT}, \langle\langle \text{Do}, a^*_2, a^*_1 \rangle\rangle\rangle\rangle\}]$$

$$C = s_1 : S_1 \wedge s_1 <_t s_2 \wedge \text{speaker}^* \prec s_1 = a^*_2 \prec s_2 \Rightarrow s_2 : S_2$$

The constraint says that if someone promises to do an action towards some audience, there is a later situation (at that location or another, depending on the promised action) where the person who made the promise ought to do as promised. The constraint, of course, cannot guarantee – and thus does not say – that the promised action will be done, it ought to be done.

Like a theory of meaning consists in validities, which are supported and made true by all situations [cf. §3], the collection of social conventions of a community consists in validities (involving deontic operators and vocabulary), which are supported and made true by all situations. They are part of the background knowledge Λ_s in a situation *s* of collective action.

As indicated by its title (Barwise & Perry 1983) and (Devlin 1991) start ST with a focus on the analysis of attitudes.

§8 Basic Ideas about Circularity

Infons can contain infons, and situations may make true infons about situations including themselves. The defining infon in a situation type can be impredicative. Forms of circularity are build-in in SF.

Situations refer to other situations in contexts where temporal order or relations between locations are relevant. The content of a prediction, say, refers to a situation to come:

$$i_1 = \quad \ll \wedge, \ll \wedge, \ll here^* =_S s^* \gg,$$

$$\ll now^* <_T s^* \gg\gg, \ll \Vdash, s^*, \ll \text{☂} \gg\gg\gg\gg$$

This infon predicts that it will rain later in the location of the situation. Talking about facts involves having infons containing the relation [⊩] of truth-making. A future state will be referred to by an infon made true by a future situation.

The situation referred to being later at that same place the information of i_1 can be also expressed by:

$$i_2 = \ll \Vdash, s_1, \{ \quad \ll \Vdash, s_2, \ll \text{☂} \gg, t_2 \gg,$$

$$t_1 <_t t_2, s_1 =_s s_2\}, t_1 \gg$$

$$s_1 \Vdash i_2$$

In this case s_1 says of itself that it will rain at its location later, and that itself makes this prediction true. In cases like this an infon talks about truth-making by some situation, and a

proposition concerning that very situation, like $[s_1 \Vdash i_2]$, makes an assertion about a situation making something about *itself* true. This exhibits some circularity with respect to truth-making.

In cases of propositions about temporal and spatial relations between situations self-reference of situations will be an unavoidable ingredient. Also, an infon referring to a future situation which *extends* the situation of utterance may have the future extended situation contain more facts which then make more constraints operational, which might *refer back* to the utterance situation. There are many variations of indirect self-reference.

Suppose a situation *s* supports a set of infons Γ. The infon

$$i \;=\; \ll \wedge, \ll \Vdash, s, \Gamma \gg, \ll \exists, i^*,$$

$$\ll \wedge, \ll \in, i^*, \Gamma, F \gg, \ll \Vdash, s, i^* \gg\gg\gg, F \gg\gg$$

expresses the *totality claim* that *s* supports *only* the infons in Γ, i.e. that Γ is total, which then can be used to ascertain which negative infons *s*, therefore, supports [cf. §6]. This seems fine, as it helps us to understand the content of totality claims. Now, we may say: $s \Vdash i$, which says that *s* supports that Γ is total, which indirectly refers back to *s* itself. Equivalently we may have $i \in \Gamma$, in which case it becomes obvious that *i* impredicatively talks of a collection it is a member of, saying in effect of *itself* that *s* supports it.

In infons like *i* we come close to paradox, since using [$\Vdash$] within an infon allows to express self-support as a variation of ascribing [True] self-referentially.

One may think most of situation and infon circularity and self-reference to be harmless as long as no semantic properties and relations are explicitly involved (like the property *True* or the relation *DenotedBy*).

$$i_3 = <<\text{True}, \alpha>>$$

This infon says that some sentence α is true. If the linguistic part of SF contains a language with enough expressive power, the semantic antinomies (like the *Liar Paradox*, using "True", and *Berry's Paradox*, using "DenotedBy") will be expressible. There will be Liar-sentences in some variation, and infons containing information about them, like

$$i_4 = << \alpha_L = \text{“}\neg\text{True}[\alpha_L]\text{”}>>$$

Any situation with $s \Vdash i_4$ will (by the typically Liar-reasoning and closure conditions) be inconsistent by containing a contradiction about an inconsistent object α_L, which will be a *part* of some situations. The antinomy (especially if provable) will be made true by all situations, which are then all inconsistent, as reality (the actual world, $w_@$, is inconsistent). All this, however, SF only inherits from semantic closure of some language it incorporates. Inasmuch as SF will be comprehensive (in dealing with the informational content of all sentences, even paradoxical ones), the inheritance of *paradoxical content* cannot be circumvented. Still, this paradoxical content

concerns our *linguistic* representational resources, our concepts of meta-representation with respect to semantics.

SF itself, however, allows to express its own antinomies, even in the absence of semantic predicates and relations. We have seen in i_1 and i_2 infons involving the relation of truth-making and thus we have a form of semantic closure in SF. [$\Vdash$] and quantification in infons suffice to have infons with a role corresponding to paradoxical sentences. For a start, an infon like

$$i_5 = <<\nVdash, s_{17c}, i_5>>$$

says of itself that some specific situation does not make it true. Semantic closure is present by the relation of truth-making and not-truth-making can be part of informational content.

An infon claiming of itself that it will not be made true by any situation says of itself that it is never made true, always not-obtaining:

$$i_L = <<\forall_@, s^*, << \nVdash, s^*, i_L>>, T>>$$

Situations are partial, but [$\Vdash$] is bivalent. SF contains a principle of *determinacy*:

$$\text{(DET)} \quad (\forall_@ s)(\forall i)((s \Vdash i) \lor \neg(s \Vdash i))$$

ST ontology and understanding of real situations must support this principle. Real situations *have* a constitution which either contains a fact (corresponding to an obtaining infon) or it does not, therefore any infon is either made true by the situation or not. By partiality both the positive and the negative infon with respect to some content may not be made true [cf. §6], but this does not violate (DET) as then the right disjunct is true for both of them.

Because we can ask, then, whether infon i_L obtains anywhere (is made true by any situation *s*) we regain antinomic reasoning.

There are plenty proposals how to deal with (semantic) antinomies (sentences where both the sentence and its negation are provable) or 'paradoxes', but proponents of paraconsistency and dialetheism (the claim that there are true contradictions, cf. Priest 2006) have argued that supposed solutions to the antinomies fall short on two grounds: (i) either their own theory is inexpressible (e.g. when talking from *nowhere* when claiming a hierarchy of truth predicates) or they fall prey, for example, to Strengthened Liars (cf. Beall 2007), (ii) they make crucial use of a object- *vs*. meta-language distinction, which leaves the semantic concepts of the meta-language untreated (cf. Priest 2006, Bremer 2005).

Approaches to the antinomies in the ST tradition are no exception to this failure. Therefore, this paragraph illustrates some basic phenomena of circularity and contradiction in SF without offering any detailed solution to the antinomies and contradictions. An advanced ST should integrate some form of paraconsistency and employ the further truth-value B (for some – supposedly semantic – relation holding and not-holding at the same time). We come back to the issue of Relevant Logic as part of SF.

In a SF of sufficient expressive power infons can be named, and infons can refer to themselves. So, we can have a Liar-type infon:

$$i_L = \langle\langle \forall_@, s^*, \langle\langle \nVdash, s^*, i_L \rangle\rangle, T \rangle\rangle$$

This infon says of itself that all real situations are such that they do not make it true: that it is not-true *tout court*. When we take some real situation *s* and ask whether $s \Vdash i_L$, immediately:

$$s \Vdash i_L \rightarrow s \nVdash i_L \ \lightning$$

So, *s* cannot make i_L true. Suppose then it does not: $s \nVdash i_L$. As situations are partial one may think one may stop here. But $s \prec w_@$, and asking the question with respect to $w_@$ blocks the way out on partiality. If the *proposition* $[w_@ \nVdash i_L]$ is true, it is absolutely true, and, by this, true at $w_@$. So, we have:

$$w_@ \Vdash \langle\langle \forall_@, s^*, \langle\langle \nVdash, s^*, i_L \rangle\rangle, F \rangle\rangle$$

By infon logical consequence this means:

$$w_@ \Vdash \langle\langle \exists_@, s^*, \langle\langle \Vdash, s^*, i_L \rangle\rangle\rangle\rangle$$

By instantiation we get for some real situation *s*:

$$s \Vdash i_L$$

and this brings us back to the contradiction:

$$s \Vdash i_L \wedge s \nVdash i_L$$

or explicit:

$$s \Vdash i_L \wedge \neg\, s \Vdash i_L$$

Given (i) the virtues of expressive power (e.g. to account for common knowledge, and cross-references between situations), (ii) the existence of a comprehensive reality ($w_@$), (iii) the levelling of the object- *vs*. meta-language distinction for a universal framework, contradictions of this type are unavoidable. They need not interfere into SF analyses in other fields. So, we may – for a start – not care, and relegate their proper treatment to some other time, like scientist – for a start – do not care about many anomalies, but relegate their proper treatment to another time.

One way to deal with paradoxes like the Liar separates the situation/context of their utterance from the situation/context of their evaluation (or the evaluation of their negation). This substitutes a hierarchy of situations/contexts for the comprehensive $w_@$, the existence of which might even be denied – a supposed discovery gained by reflecting on the paradoxes. Or one may not deny the existence of $w_@$, but deny that there are any propositions (or statements expressing them) *about* the whole world and *made true in* $w_@$. A Liar statement's reference to its very situation of utterance fails, and forces (by diagonalization) moving to another situational context, smaller than $w_@$, where the falsity of the Liar can be stated. This proposal within ST (e.g. in Barwise & Etchemendy 1987) has been acclaimed as one of the key advantages of ST (e.g. in Devlin 1997: 256-59).

First of all: variants thereof – despite Barwise's & Etchemendy's claim to follow a different route – can also be found outside ST (e.g. Simmons 1993, Blau 1983), and one may include here the classical meta-language hierarchies of Tarski (cf. Tarski 1936) and his followers (up to Kripke 1975).

And crucially: this type of proposal is unacceptable both for ST, but also on general meta-semantical grounds:

(i) Giving up $w_@$ [item (ii) above] is no option for a theory of reality as structured in and constituted by situations. Realism with respect to situation includes basic mereological principles of parthood and fusion: all real situations have a comprehensive fusion. How can it be that there no comprehensive space-time, which also serves as truth-maker for universal statements? The idea seems hardly understandable.

(ii) Once one admits the existence of $w_@$, one has to admit sentences, statements and propositions which are about it or are made true by the world. Otherwise, one lands oneself in paradoxes of inexpressibility with respect to one's own theory (of $w_@$ and the paradoxes). A solution to the Liar, for instance, talks of Liars *in general* and for *any* situation whichever. Shifting to ever new situations of evaluation for the iterated paradoxes in their respective strengthened versions recreates a hierarchy of situations, which lands one in the even more devasting *paradox of ineffability*: one talks in general about the ever new (situation) level, but the hierarchy in totality or the comprehension of all situations cannot be expressible, otherwise the paradoxes could be regained at *this* level or situation of talk (cf. Priest 2006: 18-25).

(iii) There are, although their frequency has been exaggerated in semantics and logic, plenty eternal sentences, the evaluation of which does not depend on a specific situation. Examples are axioms or analytic sentences. Paradoxes like the Liar or *Berry's Paradox* are eternal statements with correlated eternal sentences. So, shifting their evaluation and that of their negation between situations is unwarranted.

Thus, dealing with the paradoxes requires a logical solution (not an ontological solution), which means some form of paraconsistent logic.

We met a motivation for Relevant Logic in SF in §6. Given what we have seen in this paragraph we can strengthen the case for Relevant Logic in SF.

One goal of Relevant Logic has been that in a conditional there has to be some connection in content between antecedent and consequent, ensured by the 'variable sharing' requirement. This aims at blocking new content entering the consequent unrelated to the antecedent. This restriction on conditionals fits to the restrictions on IFL [in §6]. It seems the demands of IFL and the supply of Relevant Logic are made for each other, especially if one adds the demand for a paraconsistent logic if the circularity and self-reference in SF is sustained, *and* neither situations nor infons are treated as sets to be dealt with in ZFA. In the alternative between (i) turning to ZFA, but giving up realism on situations and the *sui generis* character of infons, and (ii) adopting a Relevant Logic as (propositional) basis logic in SF, the choice of a Relevant Logic seems to better preserve the core and aspirations of ST.

The new difficult questions are, then:

(i) which Relevant Logic it should be,
(ii) how to ensure 'classical recapture' (using the full force of classical higher order logic, or SOL) in those parts of SF which allow for this.

Interestingly information flow semantics has helped some Relevant Logics with the notorious issue of their deviant and peculiar semantics: the peculiar ternary modal accessibility semantics for the conditional, and the peculiarities of the semantics for negation in terms of the *Routley Star* $\ast$. [We turn, therefore, to this marriage of ST information flow theses and Relevant Logic.]

We said [in §4] that constraints can be considered as 'information channels' linking situations (including complete situations: worlds). One can consider a *ternary accessibility* relation between two situations *relative* to a specific channel:

$$\text{ACCESS}(s_1, s_2, C_1).$$

ACCESS is ternary having two situations and a channel as arguments, not three situations. This difference to other expositions places a third situation to state the access and constraint obtaining. In this situation (as support and truth-maker) everything comes together.

This ternary relation serves as backbone to the semantics of the conditional in some semantics in Relevant Logic.

The (in-)compatibility of two situations (by the conditioning infons of their types [cf. §6]) may serve in some semantics of negation in Relevant Logic.

We look first at some paradigmatic systems (like B and R). We will still use "⊃" as conditional connective, material implication not being part of IFL. Taking "⊃" as the relevant conditional connective means that it cannot be defined in the usual PC way: $\alpha \supset \gamma \equiv \neg\alpha \vee \gamma$. "⊃" captures now a connection in content, which is not truth-functional. Relevant Logics can contain (all) theorems of PC as expressed with "¬", "∨", "∧" – even theorems of the form $\neg\alpha \vee \gamma$ where α and γ *do not* share a variable, but there will be no rules of detachment for these cases. Inference rules only apply to the relevant conditional, which – with these clarifications in mind – "⊃" expresses now. Further on, remember §6 for the following exposition: rules and conditions in the *semantics* of the logical vocabulary of SF are stated on a meta-level in SF more readable and distinguishable in a formal *language* format, which could be translated into infon-talk, though, if one applied infon-talk and [⊩] all the way up to stress uniformity of outlook and semantic closure, but would be quite cumbersome to state – the inclined reader may help herself to it.

The semantics of R employs both a ternary accessibility relation as well as the *Routley Star* ∗. A ternary accessibility relation between worlds seems strange as this should mean some world accessing the accessing between two other worlds. [∗] is used to indicate for some world *w* a *witness world w** which by not making something true justifies making its negation true in the first world. This will be translated and transformed using situations, infons, and constraints, which will – presumably – make it comprehensible.

The ternary ACCESS relation serves to make conditionals true in a situation:

(1) $s_1 \Vdash \ll \text{ACCESS}, s_2, s_3, C_1 \gg$

From that situation's perspective accessibility between two situations *via* a channel is given. The channel is a constraint supported:

(2) $s_1 \Vdash \ll \Rightarrow, S_1, S_2 \gg$

with: $S_1 = [s \mid s \Vdash \varphi]$ and $S_2 = [s \mid s \Vdash \phi]$. The constraint links situations which support infon φ to those which support infon ϕ. s_1 need not be distinct from s_2 and s_3. Rather ACCESS has to be reflexive in s: $s \Vdash \ll \text{ACCESS}, s, s, C \gg$, which validates closure under *Modus Ponens* for s.

Now given (1) and (2):

(3) $s_1 \Vdash \ll s_2 : S_1 \gg$
(4) $s_1 \Vdash \ll s_3 : S_2 \gg$

together verify:

(5) $s_1 \Vdash \ll \varphi \supset \phi \gg$

for infons, and if $cont(\alpha_1) = \varphi$ and $cont(\alpha_2) = \phi$ we get:

(6) $s_1 \vDash \alpha_1 \supset \alpha_2$

In this manner the truth of conditionals grounds in constraints holding in a situation.

§6 introduced the infon <<⊥>> and the notion of incompatibility. We lay down for <<⊥>> the interchange principle

$$(\bot) \qquad \langle\langle \bot \rangle\rangle = \langle\langle \wedge, \langle\langle P, a \rangle\rangle, \langle\langle P, a, F \rangle\rangle \rangle\rangle$$

for any infon of the form <<P, a>>.

Two situations s_1, s_2 are *compatible* [COMP(s_1, s_2)] in case they do not support incompatible infons. [COMP(s_1, s_2)] can be defined:

$$(\text{COMP}) \quad \neg(\exists i_1, i_2)(i_1 \in \Gamma_{s1} \wedge i_2 \in \Gamma_{s2} \wedge \langle\langle \supset, \langle\langle \wedge, i_1, i_2 \rangle\rangle, \langle\langle \bot \rangle\rangle \rangle\rangle)$$

This definition uses [⊃] and an application of it can lead back to cases of compatibility checking, but only with respect to less complex infons, grounding the procedure of compatibility checking.

With the relation COMP(s_1, s_2) we can state the truth condition of a negation:

$$(\neg{*}a) \quad s_1 \vDash \neg\alpha \ \text{ iff } \ (\forall s_2)(\text{COMP}(s_1, s_2) \supset s_2 \nvDash \alpha)$$

A sentence has to be negated in a situation if *no* compatible situation – not just the situation itself – makes the sentence true. In terms of infons of the basic form i = <<P, a, T>> and *cont*(α) = i this becomes:

$$(\neg{*}b) \quad s_1 \Vdash \langle\langle P, a, F \rangle\rangle \quad \text{iff} \quad (\forall s_2)(\text{COMP}(s_1, s_2) \supset s_2 \nVdash \langle\langle P, a, T \rangle\rangle)$$

The condition on the right-hand side corresponds to a totality claim [cf. §6]. Totality claims (that no facts have been

overlooked) are the way to justify that a situation which does not support an infon supports the negated infon. The condition in (¬∗) is a totality claim, because collecting *all* compatible situations for s_1 amounts to considering all possible variations of facts outside of s_1, in which <<P, a>> is found, then, lacking, so that s_1 will be not be part of a larger situation s_3 (i.e. extended), $s_1 \prec s_3$, with $s_3 \Vdash \langle\langle P, a \rangle\rangle$. This maximal collection corresponds to the ‘witness world’ w* marked by the *Routley Star*. (¬∗) translates Routley’s truth-condition into ST. A negative infon obtains in a situation iff *no* witness can be found for the positive infon, given what the situation (already) contains as factual. A negation ¬α is true in a situation iff no witness can be found for α, given what is (already) true in the situation.

The restrictions on infon logic aimed at with Relevant Logic are now satisfied in two ways: (i) the Relevant Logic itself invalidates the ‘paradoxes of material implication’, and (ii) which conditionals are accepted in the first place depends on which constraints a theory or belief system endorses.

The ST-transformed truth-conditions for conditionals and negation now invite to turn to systems of Relevant Logic. The typical systems of Relevant Logic can be systematized as being extension of a basal Relevant Logic B. The two truth-conditions alone (i.e. without further restrictions on ACCESS) characterize the semantics of the system B.[12]

B is defined by the following axiom schemes and rules:

(A1)	$A \supset A$
(A2)	$A \supset A \vee B$
(A3)	$B \supset A \vee B$
(A4)	$A \wedge B \supset A$
(A5)	$A \wedge B \supset B$
(A6)	$A \wedge (B \vee C) \supset (A \wedge B) \vee (A \wedge C)$
(A7)	$(A \supset B) \wedge (A \supset C) \supset (A \supset B \wedge C)$
(A8)	$(A \supset C) \wedge (B \supset C) \supset ((A \vee B) \supset C)$
(A9)	$\neg\neg A \supset A$

(R1)	$A, A \supset B \rightarrow B$	[*Modus Ponens*]
(R2)	$A, B \rightarrow A \wedge B$	[$\wedge$Introduction]
(R3)	$A \supset B \rightarrow (C \supset A) \supset (C \supset B)$	[Prefixing]
(R4)	$A \supset B \rightarrow (B \supset C) \supset (A \supset C)$	[Suffixing]
(R5)	$A \supset \neg B \rightarrow B \supset \neg A$	[Contraposition]

[12] The transformation of the semantics of accessibility and negation may *seem* to open the door for Relevant Logic in SF. There are, unfortunately, substantial hurdles in the way. The following presentation looks at formal *language* systems, which may motivate a new part of IFL in SF, but they *are not* part of SF yet. The format, therefore, is not SF. Capital letters "A", "B", "C" stand schematically for sentences. This part just informs about candidate logics and *does not* solve the problem how to integrate Relevant Logic properly into SF.

The systems that extend B are *affixing* systems, since they all share the pre- and suffixing rules. Candidates for further axiom schemes are:

(A10)	$(A \supset \neg B) \supset (B \supset \neg A)$
(A11)	$(A \supset B) \supset ((C \supset A) \supset (C \supset B))$
(A12)	$(A \supset B) \supset ((B \supset C) \supset (A \supset C))$
(A13)	$(A \supset ((A \supset B) \supset B)$
(A14)	$(A \supset (A \supset B)) \supset (A \supset B)$

(A10) – (A12) are the theorem versions of the rules (R3) – (R5). All of these are *not* valid in B.

One can define the further systems:

DW = B + (A10) [(R5) can be dropped then]
TW = DW + (A11) + (A12) [drop (R3) and (R4)]
RW = TW + (A13) [drop (A11) *or* (A12)]
R = RW + (A14)
$T = R - (A11) + ((A \supset \neg A) \supset \neg A)$
$E = T + ((A \supset C) \supset (((A \supset C) \supset B) \supset B)$
$+ ((A \supset A) \wedge (B \supset B)) \supset ((A \wedge B) \supset (A \wedge B))$

The systems that extend B up to R are indeed relevant in the sense that in a logically true conditional the *variable sharing requirement* is met.

The systems that extend B validate more sentences by excluding more counter models by requiring *further* properties (restrictions) of the relation ACCESS (as stronger modal logics in general work by restricting accessibility).[13]

There are, however, Relevant Logics the semantics of which does not work with the ternary accessibility relation. (Brady 2006) proposes the system DJ^{d}Q as a Relevant Logic to capture the intuitive notion of ‘entailment’. Its semantics is modelled on the idea of *containment of content*. The basic idea is that a content is connected to each sentence and the relation between antecedent and consequent of a relevant conditional is that of containment of content. So, the conditional expresses a non-extensional connection between antecedent and consequent, which again fits to the idea of infon logical connections. [We will again use “⊃” for the conditional and do not call it “entailment”, which should be employed for analytic links and logically valid conditionals, whereas IFL connects infon also by empirical constraints.]

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[13] Unfortunately, these restrictions phrased for a ternary access relation await their transformation in restrictions on ACCESS, as they have no intuitive sense and can hardly be rephrased to make them sound obvious. Solving this challenge, on the other hand, may be thought less than pressing. These restrictions on accessibility in their original form employ nested existential quantification on situations/worlds, which has a most unfortunate consequence: if one uses them in a tree like decision procedure for a logic like R, this results in branches of *infinite* length. In fact, in can be proven that even propositional Relevant Logic is, therefore, *undecidable*! It can be really hard to ascertain what holds in system R. This undecidability as a *proven meta-theorem* will have to be preserved by any transformation of them into restrictions on ACCESS!

The logic DJ^{d}Q is very weak and has to assume axioms for logical relations derivable otherwise. We look only at the propositional part DJ^d:

Axiom schemes:

(A1) $A \supset A$
(A2) $A \wedge B \supset A$
(A3) $A \wedge B \supset B$
(A4) $(A \supset B) \wedge (A \supset C) \supset (A \supset B \wedge C)$
(A5) $A \supset A \vee B$
(A6) $B \supset A \vee B$
(A7) $(A \supset B) \wedge (C \supset B) \supset (A \vee C \supset B)$
(A8) $A \wedge (B \vee C) \supset A \wedge B \vee A \wedge C$
(A9) $\neg\neg A \supset A$
(A10) $(A \supset \neg B) \supset (B \supset \neg A)$
(A11) $(A \supset B) \wedge (B \supset C) \supset (A \supset C)$

Rules:

(R1) $A \supset B, A \to B$
(R2) $A, B \to A \wedge B$
(R3) $A \supset B, C \supset D \to (B \supset C) \supset (A \supset D)$

Meta-Rule: If $A \to B$ then also $A \vee C \to B \vee C$

For DJ^d–semantics works with contents. The *content* of a set of sentences Γ are all the sentences that can be *analytically established* from the terms occurring in the sentences in Γ. Often, Γ will be a singleton {A}. The *range* of Γ is the set of all sentences that analytically *ensure* that at least one sentence in Γ is true. Each sentence A corresponds a set of sentences c(A), which is its *content* (the analytic closure of A). The content set of A can be taken as a great conjunction.

For IFL the idea of the content of A would be weakened to include all the sentences (precisely: sentence contents, i.e. infons) that can be established by a (lawlike) constraint given the content of sentence A. The complete informational content of A will be the set of sentence contents (infons) constituting its closure under constraints and analytic links.

The logical operations can be semantically modelled by algebraic operations on these (content) sets. Every basic sentence is assigned some content:

The content of $A \wedge B$ is the set of analytic consequences of the union of c(A) and c(B), as both conjuncts have to be true.

The content of $A \vee B$ is $c(A) \cap c(B)$, as something can be element of the content only if in the content of both disjuncts, each sufficient for the disjunction to be true.

The conditional is now semantical defined as *containment of content*:

$$||A \supset B\,|| = T \text{ iff } c(B) \subseteq c(A).$$

To ensure a Relevant Logic postulates for content relations have to be laid down, e.g. $c(A \vee B) = c(A) \cap c(B) \subseteq c(A)$, preventing new content entering arbitrarily.

An exception to this algebra is negation, since taking negation as set complement would give $A \wedge \neg A$ universal content, and would validate *ex falso quodlibet* and *verum ex quodlibet* – all of which should be prevented. The negation of a sentence can

be better understood as all those sentences that represent *alternative* situations, i.e. the content of $\neg A$ are all facts the *absence of which* made A possible: this set is c(A)*. The intended interpretation of the language assigns c(A)* to $\neg A$.

This semantics – obviously – *presupposes* a theory of establishing the consequences of a given sentence. Either the same semantic model has to be iterated on meta-levels, which lands the semantics in the expressibility paradoxes of semantic hierarchies, *or* establishing the content of a sentence has to given some grounded model, similar to the grounding problem for compatibility COMP.

In an advanced version of SF (parts of) a propositional Relevant Logic might be integrated if either (i) all the open problems around the semantical transformation of all restrictions on ternary accessibility into situation-based semantics could be solved for logics following B, or (ii) those open problems of a grounded semantics of content containment for logic DJ^d. Even if we had achieved this, there would be the question which Relevant Logic exactly fits best to SF, and how to ensure ‘classical recapture’.

Focus on DJ^d seems most promising in this alternative. As it is a very weak logic, one should ensure that in most contexts classical reasoning can be applied.

The principled alternative consists in accepting the irrelevant consequences like *verum ex quodlibet*. The content of an infon φ would seem to get diluted by such closure conditions, but there still is a core content of φ which distinguishes φ from other (diluted) infons. One should deny defining infon identity by logical equivalence, and point to the constituents of the infon.

(Barwise & Etchemendy 1987) is an early reflection on paradox in ST. Denial of a comprehensive reality (cf. also Grim 1991 for set theoretical reasons), however, is no option. Neither is a denial that there can be statements about it, and made true by it. A paraconsistent SF may use ZFC as set theory, a dialetheist SF may use a set theory with *Naive Comprehension* (in the tradition of Routley 1979 and Brady 2006). The ST tradition opted for non-well-founded set theory ZFA (cf. Aczel 1988, Devlin 1993: 143-83).

One may think that the *hypersets* of ZFA are suited to model the circularity of ST: a situation *s* can occur in infons that are made true by *s*; the set of infons made true by *s*, which *characterizes s*, thus, one may think, leads transitively back (in being an element) to itself, as *s* occurs in some of the infons made true by *s*. This train of thought works out only if one thinks of situations as sets of infons, which they are not in SF, and infons as sets, which they are not in SF. Endorsing realism about situations, and stressing the *sui generis* character of objective informational content distinguish SF from other frameworks. Abandoning *both* a set theoretical reduction of ST may implement the above train of thought, a nominalist reduction of ST more likely will stick to realism about

situations, and thus deal with circularity in some other way [cf. the first Appendix].

The combination of information flow semantics and Relevant Logic does not follow, but is inspired by the exposition in (Mares 2004). The universal logic DJ^dQ is the central Relevant Logic in (Brady 2006), where it is also extended by an indication for 'classical' sentences to ensure 'classical recapture'.

§9 Basic Ideas about Situated Algorithms

ST places the idea of information flow center stage [as seen in previous paragraphs]. The elucidation of information flow proceeds in the manner of formal ontology model building and analysis. The basic analysis of information flow [in §4] spells out which information an information processor objectively (already) has by extracting some information in a situation by giving lists of conditions and alluding to closure conditions of infons. Information flow along constraints models the extraction of information. Such analyses, however, are ultimately *static*. They do not model *how* the information is extracted and its consequences arrived at. They deal in infons, which – as abstract entities – are not *parts* of cognitive systems [cf. §4]. To supplement an account of this requires computational models, ideally specific algorithmic blueprints. These are *procedural*. Adding computation (algorithmic analyses) to ST means putting *representations* center stage – "bringing syntax back to situation semantics" in a reversal of a founding slogan of ST. SF, of course, provides a notation. One may start by taking SF-notations *at face value* (i.e. as representations themselves not as stand-in for some abstract content beyond). Of course, representations are of interest because they refer to some content beyond, but computationally what is *beyond* plays no direct (causal) role.

From the static perspective there exists a *trivial* algorithm to model the information extracted by any information processor *a* in some situation *s* with an applicable constraint set *C*:

1. Take the set of infons supported by *s*:
   $\Gamma_s = \{ \varphi \mid s \Vdash \varphi \}$.
2. Take the set of infons known by *a* to be supported by *s*: $\Lambda_{a,s}$.
3. Take the set difference $\Gamma_s \setminus \Lambda_{a,s}$.

$\Gamma_s \setminus \Lambda_{a,s}$ is the maximum of information that *a* could extract, given *a* being attuned to the constraints *C*. Remember: $\Gamma_s = \{ \varphi \mid s \Vdash \varphi \}$ is objectively closed under the constraints set *C* (by definition of infon logical closure, cf. §6).

[In case Γ_s is not finite, the 'taking' of the sets cannot be algorithmic, instead an enumeration algorithm has to generate Γ_s stepwise, as will be done with $\Gamma_s \setminus \Lambda_{a,s}$ by stepwise difference, these steps of logical operations being algorithmic.]

Slightly more realistic variations might restrict the set *C* to constraints *C'* information processor *a* is attuned to (still IFL immediately postulates a closure set Γ_s' of supported infons given *C'*). One might also look at the stepwise closure of $\Lambda_{a,s}$ (i.e. applying *C'* one time, then re-applying it to the extended set $\Lambda_{a,s}$' etc.).

This algorithm works from a 3rd person omniscient observer perspective. It tells us nothing about how *a* from *a's* perspective goes about extracting information.

Above all is done by set theory. An informative computational model has to involves some program written in some programming language outlining the steps of information extraction.[14]

IFL principles and constraints can easily be *translated* into the format of a formal language, for which consequence can be computed in the usual manner (e.g. by an automated reasoning system in PROLOG). By such translations the semantic format of SF is transformed into (computational) syntax (e.g. *Horn-Clauses* in PROLOG). Following this approach ST reduces to known forms of logical representation and models of inference, as should be expected given the universal character of FOL as meta-theory. A *declarative* language like PROLOG by definition presents a *static* representation, which then needs to be translated in its procedural implementation. PROLOG working with the *Closed World Assumption*, and thus *Negation as Failure* stands, however, in direct conflict with the partiality of situations. One may ask, though, whether some other format may capture the ST perspective more

[14] Given hundreds of programming languages, many of which combine elements of different programming paradigms (like functional *vs.* imperative programming) and hide the lower programming level, coming with easy-to-use packaging, a perspicuous *algorithmic* analysis, nonetheless, has to be given in an *imperative* language (style), since computation ultimately (at the level of Assembler or abstractly with Turing-Machines or Programmable Register Machines) consists in step by step execution of basic instructions. Declarative languages need to specified in their (procedural) implementation as well (cf. in the ST context Black's account of ASTL, Black 1992: 26-57). This procedural specification should be taken as the proper *quality standard* to distinguish procedural computational analyses from static ones in formal ontology.

perspicuously. The challenge lays in being close to the SF format, but not reproducing the static representations of SF. Constraints can be parts of computational models in a *declarative* format (like *Horn Clauses*), which can then be used in *forward reasoning* and *backward reasoning* (cf. Kowalski 2011), or they might be implemented in an *imperative* format as functions/procedures which given some (situational) input compute a resulting/extracted output.

PROSIT (PROgramming in SItuation Theory, cf. Nakashima et al. 1988) is a programming language implemented in LISP (i.e. functional/declarative). Variables are general (i.e. not restricted to ontological categories), which runs against the concept of 'anchoring' parameters and variables in ST, employing instead standard *Unification*.

ASTL (Black 1992), also implemented in LISP, works with 'i-terms', which model infons. Situation types can be defined by them, and type assignment statements have their regular form [s : S]. Constraints are global backward reasoning rules without a set Γ of preconditions. Truth-making, however, is not relative to some individual situation, neither are the constraints, but global (in queries at the ASTL- prompt). Variables are, like in PROSIT, global and not relative to categories. Inclusions, extensions and cross-relations between situations cannot be expressed in ASTL.

Both PROSIT and ASTL, therefore grew from the then dominant style of AI programming (namely functional and/or declarative), and both deviate from central ideas of a ST model of information flow. Of course, both have an operational semantics in their implementation (their logic engine), but the functional syntax of their code files resembles the static analyses of formal ontology.

BABY-SIT (cf. Tin & Akman 1994, 1996) is an environment, based on ST, to test programs. It provides domains for the basic categories. 'Infons' look just like in SF, but are now *representations*, which are computationally processed. In 'assertion mode' entities, including situations and infons, can be introduced. Infons and situations can be named and included in other infons and situation types. Constraints can be used in forward and backward reasoning. They can contain conditions. Constraints can be either global (e.g. analytic links in meaning) or situated. Forward reasoning along such constraints models information extraction.

In all this BABY-SIT is close in spirit to SF and the basic analyses [in §4 and §5].

Using the resources of 'structures' (in an imperative language like C) or 'classes' (in object-oriented programming languages like JAVA) categories can be modelled easily. Constraints of information extraction by forward reasoning can be programmed as methods which *return* the new information given their antecedent conditions ('if-then-else' style) are fulfilled. A situation (object/instance) will contain a *collection* of *known* supported infons and a *collection* of applicable constraints. An information extraction algorithm will work *iteratively* through the collection of constraints and *search* for each

condition in the antecedent of the constraint whether a suitable infon is contained in the collection of known infons in the situation. The return values of applicable constraints will be stored in a collection of extracted information, which will be united with the collection of known supported infons of the situation, and a new cycle of information extraction may ensue, either up to the exhaustion of extractable information or breaking when hitting upon the looked-for information.

This resembles the idea of belief update by *Expansion* in theories of *Belief Revision*. Belief revision by *Contraction* and *Revision* (by the *Levi Identity* a *Contraction* followed by an *Expansion*) can then be added and given an information flow interpretation: information flow does not exclude, but includes as an option that information has to be given up (retracted). Retracting information is a way to learn something new about a situation an agent is in.

In fact, theories in the *Belief Revision* tradition offer another format of a theory of information flow in a cognitive system. They are stated in terms of (sets of) sentences and relations between (sets of) sentences. In the sense of this paragraph, they are *syntactic* theories of information flow.

The AGM-approach (cf. Gärdenfors 1988) lays down *structural conditions* for the main types of revision (Expansion, Contraction, Revision) on sets of sentences. The AGM-version may be implemented, rebuilding the belief set given the conditions of the type of revision (cf. Dixon 1994). Tennant's approach (Tennant 2012) complements such – against AGM improved – structural conditions with an *implementation* (in PROLOG). The picture of a *web of beliefs* coming with that approach stresses the justificatory (i.e. informational) *links* between (sets of) sentences. A web of beliefs corresponds to a graph data structure. And Tennant's approach can be computationally implemented in imperative programming (cf. on a JAVA implementation Bremer 2025: 87-112, with a code download link).

This non-AGM version of *Belief Revision* supports a non-modal semantics of indicative and counterfactual conditionals in terms of *Ramsey Tests*. (This might be considered an *alternative* to the analysis of conditional in ST.)

In an implementation sets as abstract objects are replaced by lists and collections (i.e. data types of some programming language). All controversial ontology reduces to representations.[15]

The main algorithm of *Expansion* [outlined above] will at least be *quadratic* in time complexity in the size of the larger of the two collections (constraints and infons) – for a single run, but transitive closure by constraints requires further runs on an *extended* infon collection. *Revision* (by maintaining consistency) will be at least *exponential* in time complexity in the size of justificatory connections between sentences. Updating information, thus, comes as a challenging cognitive task.

[15] So, implementing an imperative model of information flow in *Situation Theory* might be an exercise for the inclined reader, maybe taking hints from the implementations of theories of *Belief Revision*.

For ST as for other computational models of cognition, thus, one further concern with procedures referring to the fine-grained representational resources of humans is computational complexity – an advanced issues not to be dealt with here. Tests of (in)validity of inference are typically exponential in the representational resources. Problems have to be simplified or approximated to be human feasible (cf. van Rooij et al. 2019).

Early papers considering computation in a ST framework are (Hideyuki 1988), (Tin & Akman 1994). (Black 1992) introduced the ST based language ASTL.

Appendix 1

Basic Ideas about Reductions

On first impression when looking at the notation and conventions laid out in SF, and on occasion (say, when looking at infon logic [§6]) one might get the impression – or suspicion – that ST apart from an ontology of situations (reminding again on ontologies of states of affairs, like Armstrong 1997) with SF introduces just a fancy notation for what has been and is done by formal languages and model theory. Even the idea of infons as objective abstract contents reminds one on ontologies of propositions, like (Merricks 2015). This impression has some basis in the workings of SF. Sometimes in the ST tradition at least some meta-theory of some SF has been rendered in FOL, after all. Nonetheless, the crucial justification of ST and SF grounds in the benefits of this type of ontological framework for objective content. It provides (i) an account of objective information extraction and information, which is language independent – as information content should be – and can be applied to information processors which are not language users (§4), and (ii) is best suited to model situated language use by generic sentences the type meaning of which has to be situationally anchored to yield the token meaning of an utterance (§5). These basic merits as justification for using ST and SF were, therefore, included in this outline of SF itself.

Nonetheless, reductions of SF may be a project to bring ST and SF in line with known approaches and methods. This may

even be – in the light of ST founding slogan of "Bringing ontology back to semantics!" – *counterrevolutional*:

"Driving (excessive) ontology out of Situation Theory!".

*

In case of SF a *reduction* in the sense of the second step of theory development [in §1] could employ set theory. There may be a set theoretical reduction starting from situations as urelements (Modell 1) or – more radical – forsakes also these urelements (Modell 2).

Modell 1. For a proponent of set theoretical modelling the reduction of SF might proceed by (i) modifying set theory ZF by exchanging the Foundation Axiom (Axiom of Regularity) with the Anti-Foundation Axiom, yielding non-well-founded set theory ZFA, (ii) using the set of real situation as set of urelements, yielding ZFAU, (iii) constructing everything else (including locations, times, and individuals) by set theory (i.e. by abstraction, and modelling infons as tuples, relations as sets of tuples etc.). This would reduce the ontological commitment to adopting the category of real situations, everything else being like committing oneself to set theory. The set theoretical construction will be somewhat involved and postulates for set theoretical substitutes for variable objects and *possibilia* may give an impression of arbitrariness. On the other hand, the reduction shows that *in principle* set theory and real situations suffice, and that use of SF carries no further commitments.

Modell 2. In a radicalized picture of non-well-foundedness one may forsake situations as urelements and construe situations also as sets, supposedly of sets which themselves directly or indirectly contain situations. This approach tries to transform SF into *pure* set theory. This might turn out to be intricate and involved quickly.

*

A nominalist reduction aims at getting rid of the controversial posits of ST. SF will be understood as a *representational framework* (a *formal language*, structured into sub-languages for the different purposes covered). The principles of SF are axioms and theorems of this linguistic framework.

The most controversial posits are: *possibilia*, truth-values as objects, and especially variable objects. Abstract objects can first be reduced to sets in one's preferred set theory. This could mean using set theory ZFCU, a well-established standard set theory. Reductionist may accept the paradoxes as anomalies, or deal paraconsistently with the paradoxes, using a paraconsistent logic and a stronger set theory (say, including *Naive Comprehension*). They should refuse, however, the reduction of infons to sets, given the central ST notion of information 'out there' in reality. Even less likely will be reducing infons to sets *plus* using ZFA, since this may also require abandoning realism about real situations [cf. §8]. The debate around paraconsistency and dealing with the paradoxes should be engaged with independently of the debate around ways to reduce SF. Let us assume the reductionist has settled for some option on dealing with circularity and the threat of paradoxes. The main issue of the remaining central debate will, then, be the status of the reducing entities, especially the status of sets. Set theory may

well be acceptable once the nominalist reduction takes a *fictionalist* stance on set theory, which is viable and has been articulated within some philosophies of logic and mathematics (cf. Bremer 2013: 53-60).

Real situations as chunks of reality are acceptable for the nominalist, as is reality. Real individuals, properties and relations are uniformities across real situations. In a 4-dimensionalist understanding of individuals they are real situations themselves. Properties and relations are not abstract in a mysterious or Platonist sense, but abstract in the sense of existing where the individuals are, which have these properties or stand in these relations. Token property instances can be taken as in *trope* ontologies (i.e. concrete entities) or Aristotelian universals *ante rem* (cf. the discussion in Armstrong 1978). Properties and relations can also be taken as sets, given the fictionalist understanding of set theory.

The actual world (reality) comprises at most the past and the present, the future is open – like in versions of *presentism* (cf. Bourne 2006) or theories of a growing world history (cf. McCall 1994). The future and (other) 'possible worlds' are represented as sets of sentences, like in *modal linguistic ersatzism* (cf. critical: Lewis 1986: 136-65, cf. affirmative: Bremer 2025: 24-64).

The central step in a nominalist reduction consists in a *re-interpretation of infons*.

SF so far is a notational framework, which claims an ontological realist understanding of infons (as containing entities of different categories). The nominalist takes over the notational framework, but *re-interprets it as a Semantic Representation Language* (SRL, part of the nominalist SF linguistic framework). Infons are representations in this SRL of the informational content of sentences and other representations. IFL collects the related logical principles. Infons as SRL do not contain entities, but general terms (prominently the infon framing general terms) and singular terms (for individuals), variables (instead of variable objects), and representations of supposed truth-values claimed in the statements the infons are contents of. Not all terms need to refer. The nominalist re-interpretation uses some form of Free Logic with non-referring terms. *Possibilia* drop out of the picture. This resembles the use of *Intensional Logic* (IL) as semantic representation language in *Montague Grammar* (cf. Cann 1993). Basic SRL as in the current SF is less intensional than IL. Compared to the natural language sentences, the content of which it expresses, SRL displays more structure, but it is rather transparent in comparison to higher order functional IL. So, SRL is the infon representation format connected with infon logic (IFL), SF is the broader framework of ST including meta-theory (like ontology). SRL is employed talking about sentence contents and the information situationally present in information flow.

The reduction to representations (with contents) assumes an employment of ST and SF to analyses of human languages, and analyses of information flow that involve cognitive agents. These agents use representations. The nominalist reduction works with some form of *Representational Theory of Mind*. Whatever the representations are the cognitive

agents use themselves, they may either be translated into the representational format of SF or at least their informational content can be rendered in a 3rd person perspective by SRL. Only those agents are *using* constraints or are attuned to them in their *cognitive design*. They can only extract information they have representational resources for. If from a 3rd person outside perspective some information *i* extractable from a situation *s* is described using representational resources the agent – or even information processing system – cannot represent in its design or conceptual scheme, then the agent – or even information processing system – does *not have* this information, even if from a 3rd person broader perspective *it is there* [cf. §4 and §6].

Information flow in nature is mostly a metaphor (based in the information extraction by cognitive agents), and the causal dependencies discovered in this perspective can be expressed in scientific theories which need not refer to informational content – ‘content’ of what, for whom? For many information processing systems which are not cognitive agents describing them as information extractors stresses the objectivity of information flow in the similar case of cognitive agents, and describing them this way may explain their design and purpose. In their case, however, these descriptions will always be replaceable by physical descriptions.

Seligman’s model “Physical Situations and Information Flow” (Seligman 1990) in title and doctrine places itself within ST, in practice model theory rules (e.g. situations are functions – ! – from locations and times to states which are defined by conditions defined by propositions as sets, and constraints are modelled by partial functions on situation functions, etc.).

A proper nominalist reduction employing only entities acceptable for a nominalist puts forth corresponding constructions, which may look and feel quite cumbersome. The approach – as hinted at here – however, seems feasible, again *in principle*, and with the real re-construction indefinitely postponed [cf. §1] the nominalist can use the non-reduced SF as outlined [in §§2-8].

In the perspective of seeing SF as *a Semantic Representation Language* time spend in developing SF and using it in epistemological or linguistic analyses has not been wasted, for the nominalist Logical Empiricist, or anyone with such inclinations.

*

So, both the set theorist as well as the nominalist despite their doubts about the ontological *credo* of the ST tradition need not have scruples to employ SF in any analysis related to information flow and informational content.

Appendix 2

Basic Ideas about Evaluation

Having gone through the basics of Situation Theory, and having seen at least some intricacies of its analyses, and the role ontology plays there, one may ask oneself, (i) what merits ST possesses which may motivate pursuing it in more depth, developing SF further on, and (ii) whether this further (comparatively newer approach) brings anything that could not be dealt with in other (older) approaches (like Montague/Categorial Grammar, Model Theory...), or whether it cannot compete with them in the first place.

This appendix argues for some merits of ST (i) as a ontological foundation of a realist theory of truth, (ii) a better model of situated language usage and the ‘efficiency of language’, (iii) a model of *general* information flow.

If SF-infons are re-interpreted [like in Appendix 1] as constituting a SRL, and situation ontology is kept in place, situation ontology serves as the core of a realist truth-maker semantics, which correlates expressions of linguistic categories to their referents (including true statements referring to facts, their combination expressed by infons. And a realist theory of truth and truth-making should be preferred to various forms of anti-realism or inferential role semantics. So, ST deservedly achieved bringing situation into the center of semantics. This may justify adding at least parts of it to the building blocks of a *theory of truth*, and thus giving it – by direct or indirect connections of a theory of truth, despite its original metaphysics mongering – a role in *epistemology*. [Use I]

Once we have a reading of infons as SRL in the manner of Montague Grammar's IL, the question of comparative advantages arises. The contrast, so far at the basic level, it needs to be stressed, has SRL as a transparent representation of informational content, structural elements being the order of items in infons and logical vocabulary as known from logical systems. Montague/Categorial Grammar, on the other hand, aims at a much more thorough explanation of linguistic structure, which (i) establishes *constructively* a format of functional application which explains the unity of linguistic items (i.e. the functional unity of sentences and phrases), and does so (ii) in a way matching syntactic and semantic operations in a correspondence. Related approaches like semantics in Generative Grammar (cf. Heim & Kratzer 1998, but also Jackendoff 1983, 1990) or Lexical-Functional Grammar (cf. Falk 2011) follow essentially the same strategy, although differing in their theoretical manifestos and views on the use of higher order intensional logic, or even FOL.

One may expect (looking at the employment of ST in linguistic analyses) that developing ST and SF as SRL in the direction of being more appropriate to linguistic structure will result in extensions and modifications of infon format and logic which will move SF in the direction of these other approaches. In this perspective one may doubt what the benefit of such a repetition of analytic work should be. Categorial Grammar

combines its sophisticated analyses with a realist stance (as witnessed by its central use of Model Theory), which might be improved by the integration of the category of situations (maybe replacing truth-values as basic category).

What Situation Semantics (and its SRL format) deal with better than the other approaches is the analysis of *situated language usage* by anchoring meaning with underspecified reference in a situation (a.k.a. 'the efficiency of language' – to express different content by the same sentence used in different situational constellations). The eternal sentences of Model Theory are in everyday language the exception, not the standard. Given anchored content (i.e. having fixed a proposition) Model Theory can begin its work – ST/SF/SRL provides a systematic model – and ideally procedures – to arrive there. Thus, linguistic analysis in the borderland and intersection of semantics and pragmatics may justify adding ST/SF/SRL as approach to the other approaches *in linguistics*. [Use II]

A further justification to work with SRL, even in its 'unsophisticated' structure, stems from its use to model information flow independently of spoken languages. Analyses of information processors and cognitive agents look at systems which often do not use a natural language, but other representations. Infons serve, then, as central in ST, as descriptions of informational content of whatever representations, described from the 3rd person perspective of the cognitive scientist. No Categorial Grammar should be present here. A goal of this use of ST/SF/SRL could be to reveal more sophisticated structure in infons, but a structure relative to an explanation or etiology of the information processor under investigation.

Thus, in this line of justification ST really is *centrally a theory of information flow* (situated information flow), which reaches into semantics as understanding sentences is a form of information flow, while meaning is both relational and based in categories and their external referents, but which is *not* a grammar, nor strives at sophisticated syntactic analyses of natural language. This may justify adding ST/SF/SRL as approach to other formal approaches *in Cognitive Science*. This is underlined by its resources in describing information extraction by animals [cf. §§4 and 7], i.e. the benefits of adding such to the repertoire of *Cognitive Ethology*. [Use III]

Given the possibly fruitful Uses I – III of ST/SF/SRL working out the details of infon logic may be an exciting exercise for logicians with a broader perspective, or a nuisance for anyone (else) only interested in the Uses I – III, but needs to be accomplished at least to a degree to support them.[16]

[16] This, and advancing Uses I – III, is left as 'an exercise to the reader'.

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