Being Informative
Information as Information Handling

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Abstract. The core aim of this paper is to provide an overview of the benefits of a formal approach to information as being informative. It is argued that handling information-like objects can be seen as more fundamental than the notion of information itself. Starting from theories of semantic information, it is shown that these leave being informative out of the picture by choosing a logical framework which is essentially classical. Based on arguments in favour of logical pluralism, a formal approach of information handling inspired by non-classical logics is outlined.

1 Introduction and Motivation

Considering Floridi's recent accounts of semantic information - basically information as content - (see: Floridi [2004, to appear]), a non-realistically[1] inclined reader might be struck by its strict divide between so-called *declarative objective and semantic information* (DOS) on one hand, and *interested information* on the other. While the former refers to what semantic information *really* is, the latter is mainly considered a topic within Decision Theory. Applying that kind of divide results, however, in the immunity of theories of semantic information from pragmatically inspired critiques - for the pragmatic approach is equated with the notion of interested information. Taking this immunity into account, the necessary truthfulness of semantic information, as advocated by Floridi [to appear], becomes hard to challenge. On the other hand there still remains a rather important idealisation at the heart of his account. One way to avoid the latter is to put the user, hence the process of deduction, back into the picture and simultaneously try to retain the objective character of semantic information.

Contrary to what might be expected, presenting information as essentially *being informative* does not lead straight to interested information. It still aims at what information is, and leaves enough room for the distinction between

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[1] By the realist position we refer in the first place to the (weak) realism held by Floridi stating that information has a user-independent semantics, not to the stronger realist position from Dretske (Floridi [to appear], 6). Non-realism refers to the rejection of metaphysical realism, not to anti-realism which rejects the existence of reality.

information and misinformation from Floridi [to appear]. The core of such an approach rests on the rejection of total user-independence and the replacement of a result-based by a process-based perspective on information. It relies on handling information-like objects (both information and pseudo-information), and is motivated with regard to feasibility concerns (the information-misinformation divide is both computationally and epistemologically too demanding).

The argument in favour of a *logic of information handling* is presented in two ways. First it is shown that prevailing accounts of semantic information are, through their realism, committed to logical monism, and more precisely to a classical logical framework. Secondly an alternative logical framework inspired by adaptive logics is sketched. Again, this is carried out in two steps. (i) By introducing the notion of internal dynamics for the classical propositional case and sketching a dynamic modal framework based on it. (ii) By giving a general outline of adaptive logics and showing how it alters the notion of information. While (i) reviews previous work from Allo [to appear], (ii) gives a glimpse of forthcoming work on the informational dynamics in adaptive logics.

2 Definitions of Semantic Information and its Revisions

As mentioned earlier, Floridi [to appear] revises the standard definition of semantic information (SDI) as meaningful data by replacing its alethic neutrality (AN) by the necessary truthfulness of DOS. Following his outline we have this definition (the underlying formalism stems from situation logic, see Devlin [1991]): An infon σ classifies as declarative objective semantic information iff: (i) σ consists of a *non-empty* set (D) of data (d), (ii) the data in D are *well-formed* (wfd)), and (iii) the wfd in D are *meaningful* (mwfd $= \delta$).

This standard definition remains neutral at four levels: (i) Taxonomic Neutrality (TaxN): a datum is a relational entity (the classification of the relata remains unspecified); (ii) Ontological Neutrality (ON): no information without representation (but the nature of the representation is left open); (iii) Genetic Neutrality (GN): δ in D have a user-independent semantics; (iv) Alethic Neutrality (AN): *being information* is independent from truth.

For the present purpose the focus is on GN and AN, while TaxN and ON are taken for granted. Within this definition, GN (which is explicitly supported by Floridi) exemplifies the realism behind SDI and its revised counterpart. It does not only support the possibility of information without an informed subject, it moreover claims that meaning rests on an embedded, hence given semantics. This view is obviously only one step away from accepting a unique semantics, and hence a true logic. AN, on the other hand, is considered more problematic as it entails among other things that (i) false information is a kind of information, and (ii) tautologies qualify as information. Both consequences are rejected by Floridi because (contingently and necessarily) false information as well as tautologies cannot lead to (new) knowledge. The revision proposed in Floridi [to appear] aims at the incorporation of the necessary truthfulness of semantic information, an all too stringent restriction challenged in the sequel by claiming that (i) presumedly true information leads to defeasible knowledge, and (ii) tautologies can lead to new knowledge as soon as logical omniscience is restricted.

In showing that theories of semantic information rely on a classic-like logical framework (Situation Logic is not classical in the traditional sense), SDI as well as the more constrained Theories of Weakly and Strongly Semantic Information (TWSI and TSSI) are considered. As mentioned, SDI already refers to a fixed semantics and user-independence, both features traditionally connected to logical monism. With respect to the existence of a fixed semantics, the controversy on the possibility of logical deviance (see Paoli [2003] for a recent overview) provides a well known example. The alleged user-independence of classical logic, on the other hand, surfaces as we consider the way it defines logical consequence as truth preservation over all cases where the cases are Tarskian Models or possible worlds (Beall & Restall [2000], section 3). The connection between the latter and user-independence turns even more obvious when considered in connection with epistemic logic where it necessarily leads to full-strength logical and deductive omniscience. Moreover, as pointed out by Whitsey [to appear], epistemic logics relying on incomplete worlds (e.g. situations) still lead to deductive omniscience. Therefore logical frameworks relying on classical as well as on situation semantics can be considered as essentially user-independent and result-based approaches.

As SDI only provides a broad and general definition, it does not refer to a specific language or semantics. TWSI, the original theory of semantic information as outlined in Carnap & Bar-Hillel [1952] and revised in Floridi [2004], is more precise on the topic. It relies on (1) and entails (2) and (BCP):

(1)	$\text{CONT}(\sigma) =_{def}$	the set of all state descriptions inconsistent with σ
(2)	$\text{CONT}(\top) =$	MIN
(BCP)	$\text{CONT}(\bot) =$	MAX

Defining the semantic content of σ as in (1) by equating it with the state descriptions it excludes[2], tautologies have minimal semantic content - they exclude nothing - while contradictions have maximal content - they exclude everything. This seems inevitable as tautologies hold for all state descriptions while contradictions hold in none (the former causes logical omniscience in modal epistemic logic). Because of the unacceptability of especially (BCP) - the Bar-Hillel-Carnap Paradox - different revisions of TWSI were proposed. The proposal from Floridi [2004], for instance, adheres to the strong semantic principle that truth-values are encapsulated in semantic information, and thus ascribes zero-content to contradictions, but considers (2) fairly unproblematic. At this point two fundamental presuppositions from Classical Logic become apparent: state descriptions are considered complete as well as consistent. Concretely it means that while any state description does not necessarily contain a complete description of the world (it is not complete like possible worlds are), it is nevertheless closed under (some kind of) logical consequence relation and contains no contradictions[3].

[2] E.g. the information A excludes all state descriptions at which A is false.

[3] Note that we rely more on a modal-epistemic view, than on the probabilistic approach adopted by Carnap & Bar-Hillel and Floridi. This change in perspective, however, does not affect the drawn conclusions.

While weak and strong semantic principles disagree with respect to the informational content of contradictions, they do agree that they cannot be true in any state description. The latter point has, by now, been challenged by several paraconsistent logicians - dialethists as well as non-dialethists[4] - claiming that at least some state descriptions, while not necessarily being real possibilities, might contain inconsistent valuations (Paoli [2003], 533-534; Priest [2002], 303-312). Without going into the technicalities of different paraconsistent logics, it is clear that (BCP) is no longer a necessary conclusion of (1). As soon as we adhere to some kind of logical pluralism (Beall & Restall [2000]) classical logic is no longer the One True Logic. Paraconsistent logics, or generally non-classical logics, thus become equally valuable in trying to deal with information[5].

Accordingly, a similar conclusion with respect to the informational content of logical consequences arises once deductive closure is restricted. Moreover it is obvious that both (2) and (BCP) are two sides of the same coin as they jointly disappear once we allow non-standard state descriptions. In the sequel both are tackled within a single framework by: (i) allowing for non-standard state descriptions (possibly inconsistent and no closure), and (ii) taking proof-dynamics seriously (no closure). The next section introduces (ii).

3 Making Internal Dynamics Explicit

When one mentions dynamics within the context of logic it is generally as a reference to external dynamics, more precisely the withdrawal of conclusions in view of some new premises in a non-monotonic logic. This is however only one side of the dynamics at work within a logical system. As the development of adaptive logics[6] exemplifies, a lot of interesting (non-monotonic) reasoning can only be adequately formalised if it equally provides an account of internal dynamics. Contrary to external dynamics, internal dynamics do not rely on new information, but only on gaining more insight. As shown in Batens [2001a] for the pure logic of relevant implication, even some monotonic logics can be characterised by a dynamic proof theory, hence as reasoning involving an internal (non-monotonic) dynamics[7].

Relying on the block-semantics, originally conceived in Batens [1995] to provide a semantical counterpart for non-monotonic dynamic proofs, the internal dynamics within classical propositional proofs can be made apparent[8]. The basic

[4] While the dialethist takes some contradictions to be true, the non-dialethist merely allows for some inconsistent valuations as a means to avoid triviality.

[5] To restrict closure the classical-intuitionistic-relevant tripartite presented by Beall and Restall should be extended with truth-preservation over block-models.

[6] See Batens [2001b] for a general characterisation, more on adaptive logics in sect. 4.

[7] Not only adaptive logics pay attention to the process of deduction, see for instance timed-reasoning-logics which take the duration of deductive processes into account (Alechina et al. [2004], Whitsey [to appear]).

[8] Note that this kind of dynamics does not involve the withdrawal of conclusions within a proof, whereas the dynamic proof-theory for the pure logic of relevant implication, despite the monotonicity of its consequence relation, does.

idea underlying block-semantics is to assign for each stage of a proof a minimal understanding in the premises needed at that stage. This method can be used unambiguously for most proof-formats, e.g. Fitch-style proofs, or analytic tableaux. In the sequel we focus on the latter.

Following the definition from Batens [1995], a block is a formula, sentence, or term, that is considered as an unanalysed entity. The things we manipulate within a proof are blocks and block-formulas. Applying this within the context of analytic tableaux, the application of tableau-rules on blocks exhibits their informativeness. When relying on Smullyan's distinction between conjunctively (α) and disjunctively (β) acting formulas, block-analysis can be represented in this way: $[\![\alpha]\!] \longrightarrow_\alpha [\![\alpha_1]\!] \wedge [\![\alpha_2]\!]$ and $[\![\beta]\!] \longrightarrow_\beta [\![\beta_1]\!] \vee [\![\beta_2]\!]$.

Thus, an α-rule restricts the set of models validating $[\![\alpha]\!]$ (but not necessarily its sub-blocks) to the set of models validating its sub-blocks $[\![\alpha_1]\!]$ and $[\![\alpha_2]\!]$. Likewise, a β-rule restricts the set of models validating $[\![\beta]\!]$ (but possibly none of its sub-blocks) to the set of models validating at least one of its sub-blocks $[\![\beta_1]\!]$ and $[\![\beta_2]\!]$. Starting from these basics, a dynamic modal logic representing the way blocks are analysed is devised in Allo [to appear]. Instead of repeating it as a whole, only its main features are enumerated. Consider each stage of a tableau-construction as a state within a relational structure, and take each transition within that structure as labelled with its correspondent tableau-rule (α or β). This results in a labelled transition system (LTS) whose paths represent all possible tableau-constructions starting from a given root-stage (i.e. the unanalysed premise-set Γ). As every path can be rewritten as an actual tableau, its general form expressed within the language of dynamic modal logic is the compound program: $\langle(\alpha \cup \beta)^k\rangle$. A terminating tableau is given for $k \geq n$ for n being the sum of all block-complexities at the root-stage.

Using the same block-language for a modal epistemic logic, it is possible to represent an insight-aware agent. Concretely, it enables the differentiation between $K[\![\alpha]\!]$ and $K([\![\alpha_1]\!] \& [\![\alpha_2]\!])$. Moreover, by adding transitions in the object-language (like in dynamic epistemic logic) it is possible to recapture the connection between the knowledge of an unanalysed block and the knowledge of its sub-blocks. This, again, can be represented as an LTS in which internal as well as external dynamics are represented in a similar way. In the following example β-transitions stand for block-analysis, whereas π-transitions stand for learning the falsehood of β_1 (loosely represented by its classical negation).

$$\begin{array}{ccc}
K[\![\beta]\!] & \longrightarrow_\beta & K([\![\beta_1]\!] \vee [\![\beta_2]\!]) \\
\downarrow_\pi & & \downarrow_\pi \\
K([\![\beta]\!] \ \& \ \neg[\![\beta_1]\!]) & \longrightarrow_\beta & K[\![\beta_2]\!]
\end{array}$$

Relying on such a representation of *informative* steps, Veltman's [1996] idea of representing information as the change it induces on one's knowledge is retained, but only insofar as one's insight in its knowledge allows for. In other words, the change is only complete for the limiting case: the end of the deductive process. As this way of looking at information moreover relies on a rule-based view on logic, it immediately presents another way of looking at logical truths. While in this approach logical truths do not add any information (it does not correspond to any informative step within the structure), putting the logic at work is informative in the same way new information is (both can be modelled as transitions or as programs). On this point, the present model clearly challenges some presuppositions from classical definitions of semantic information while it maintains its objectivity because informative steps (epistemic programs) do not depend on a specific knower. With respect to the informational content of contradictions, and the distinction between information and misinformation, the present approach does not yet offer a pragmatic alternative. The next section focusses on these points as well as on the case of tautologies.

4 Semantic Information and Adaptive Logics

While adaptive logics where originally designed as inconsistency adaptive logics (non-monotonic paraconsistent logics, sometimes considered as a classical recapture within a paraconsistent setting, Priest [2002], 347-351), their development has shown the wider range of applicability of their basic insight. That is: consider a logic as (i) a set of conditional and unconditional rules, and (ii) a strategy describing how the applicability of conditional rules is contextually restricted. At the level of proofs, the logic relies on the provisional application of conditional rules unless and until it leads to an abnormality (this is defined by the strategy - reliability or minimal abnormality). Semantically, logical truth and consequence are defined over all reliable / minimally abnormal models of the premises. For each strategy, a notion of final derivability is definable which is complete with respect to the corresponding semantics (Batens [2001b], 61-63).

Taking an adaptive logic as an underlying framework for defining semantic information, significantly alters the theory's original features. First, and most importantly, as models can contain abnormalities (e.g. be inconsistent), contradictory information is no longer too informative. For instance, if an agent reasoning with an inconsistency adaptive logic knows Γ, for $\Gamma \models A$, and then learns that $\sim A$ is the case, its knowledge will change from truth in all adaptive (minimal abnormal or reliable) models of Γ to truth in all adaptive models $\Gamma \cup \{\sim A\}$ (this non-monotonic change cannot be modelled by a regular update). Thus, contradictions do not entail too much. They do not exclude all possible worlds (models) for some of them might contain inconsistencies (see also Priest [2002], 377-378 on paraconsistency as a *safe* way to deal with information)[9].

The latter is, however, not the only change induced by the logic. The way adaptive logics rely on the context (i.e. the premise-set) to define logical consequence has an interesting effect which is independent from its paraconsistency. Viz. adaptive logics have no theorems of their own, or in other words: the empty set has no adaptive models (Batens [2001b], 56). As a consequence finally deriving an instance of a tautology in a certain context is genuinely informative as

[9] The situation in non-adaptive paraconsistent logic is quite different, for knowing the truth of A does not necessarily involve knowing whether $\sim A$ is true or false (whereas adaptive logics *presume* its falsity). In that case, learning $\sim A$ is informative as it rules out the state descriptions at which $\sim A$ is false.

it provides meta-information on the context of reasoning, while deriving it at a stage provides at least a useful local criterion. As an example: if $\sim (p \,\&\, \sim p)$ is finally derived / true at all adaptive models of Γ, p behaves *normally* within that context; if this is the case for any literal in Γ, then the whole context behaves *normally* with respect to a specific strategy.

Whereas the previous examples show the benefits of using adaptive logics to model information in a very general way, the last example is more concrete. In the remainder of this section an adaptive logic (based on discussive adaptive logics) for acceptance and rejection is outlined, and it is argued that it forms a plausible model for handling information-like objects (henceforth ILO). Let any set Γ of ILO's be represented in the following way: $\Gamma^{\Diamond} = \{\Diamond A \mid A \in \Gamma\}$, then every $\Diamond A$ is either information or misinformation (read $\Diamond A$ as A might be true). Unconditional reasoning from these objects is based on a modal logic (e.g. S5), thus restricting any reasoning from two or more ILO's (adjunction fails, see Priest [2002], 299-302). Conditional reasoning is based on the so-called Triv-axiom: $\Diamond A \supset \Box A$, and represents the provisional acceptance of an ILO (read $\Box A$ as A is presumed true). The underlying idea is that ILO's are presumed true unless and until this presumption leads to an abnormality, or in other words: ILO's are by default treated as information ($\Box A$ on the condition $\{A\}$). This practice of reasoning by default is, from a pragmatical point of view, considered as the best option for both human and artificial bounded reasoners. Moreover, the notion of final derivability provides us with a pragmatically acceptable notion of information as finally accepted ILO for a given context (set of premises) Γ.

If, moreover, we accept Rescher's claim that putative and real truth are factually indistinguishable (Rescher [2001], 17), a finally accepted ILO satisfies the necessary truthfulness condition proposed by Floridi, but only (i) locally (for a given and fixed context Γ), and (ii) for the limiting case of being finally derived (i.e. full insight in Γ). This is the only pragmatically acceptable way to consider the information-misinformation divide, namely as a computationally expensive or even undecidable property within a given context. Considering the process of deduction as prior to the notion of final derivability, truthfulness becomes negotiable, and reasoning turns out to be driven by the mentioned divide.

Finally it should be mentioned that within game-theoretical semantics (GTS) negotiating and reasoning are closely related, and that GTS allows a very natural and pragmatically appealing characterisation of final derivability (for every move of falsifier, verifier has a counter-move).

5 Concluding Remarks

In this paper it was shown that theories of semantic information, as they were defined by Carnap & Bar-Hillel, and by Floridi strongly rely on informational realism and only give an account of information as a final product. An alternative approach was outlined relying on non-classical logic, and more precisely on the view that logic should not only focus on the relation between premises and conclusions, but also give a proper account of the process of deduction (conclusions are not instantaneous and are defeasible). From this perspective the conceptual problems regarding the informational content of logical truths and necessary falsities (contradictions) are almost solved for free.

Moreover it turns out that in an adaptive logic for acceptance and rejection a weak but sufficient notion of truthfulness is obtained for the limiting case of final derivability (this solves the problem of contingent falsities). Contrary to the motivations of Carnap & Bar-Hillel [1952], the presented approach outlines a theory of information based on information handling, not the other way around as a theory of semantic information as a preliminary for a future theory of pragmatic information. Finally the notions of ILO and ILO-handling, turn out to be closer to commonsensical uses of the notion of information.

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