Is Information Meaningful Data?

L. L. Floridi
Sub-Faculties of Philosophy and Computing
University of Oxford
Wolfson College
Oxford, OX2 6UD, UK
luciano.floridi@philosophy.oxford.ac.uk

Abstract

There is not yet consensus on the definition of semantic information. This paper contributes to the current debate by criticising and revising the Standard Definition of objective semantic Information (SDI) as meaningful data. The main thesis defended is that semantic information encapsulates truth, so that meaningful and well-formed data constitute information only if they also qualify as truthful. After a brief introduction, SDI is analysed and then criticised for providing necessary but insufficient conditions for the definition of information. SDI is incorrect because truth-values do not supervene on information, and misinformation (i.e. false information) is not a type of information, but pseudo-information, i.e. not information at all. This is shown by arguing that none of the reasons to interpret misinformation as a type of information is convincing, whilst there are compelling reasons to treat it as pseudo-information. As a consequence, SDI is revised to include a truth-condition. The last section summarises the main results of the paper and indicates some important consequences of the new formulation.

Keywords

Alethic values, Deflationary theories of truth, Dretske, Geach, Grice, Information Theory, Semantic Information, Standard Definition of Information.

1. Introduction

Recent surveys[1] have shown no consensus on a single, unified definition of information. This is hardly surprising. Information is such a powerful and elusive concept that, as an explicandum, it can be associated with several explanations, depending on the cluster of requirements and desiderata that orientate a theory (Bar-Hillel and Carnap [1953], Szaniawski [1984]). Claude Shannon, for example, remarked that

> The word "information" has been given different meanings by various writers in the general field of information theory. It is likely that at least a number of these will prove sufficiently useful in certain applications to deserve further study and permanent recognition. *It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general field*. (from "The Lattice Theory of Information", in Shannon [1993] pp. 180-183, first sentence, italics added).

Polysemantic concepts such as information can therefore be fruitfully defined only relatively to a well-specified context of application. Following this localist principle, this paper analyses only a crucial aspect of a specific type of information, namely the alethic nature of objective semantic information (more on this shortly). The problem addressed by this paper is: are alethic values supervenient on objective semantic information, as presumed by the standard definition of information (SDI)? The paper argues for a negative answer: semantic information encapsulates truth, so that "true information" is simply redundant and "false information", i.e. misinformation, is merely pseudo-information. The important consequences of this conclusion are clarified in the last section.

2. The Standard Definition of Information

Intuitively, "information" is often used to refer to non-mental, user-independent, semantic contents, embedded in physical implementations like databases, encyclopaedias, web sites, television programmes and so on (Buckland [1991]), which can be variously produced, collected, accessed and processed. The analysis of this popular concept of *objective semantic information* is not immediately connected to levels of subjective uncertainty and ignorance, to probability distributions, to utility-functions for decision-making processes, or to the analysis of communication processes. Thus, the various, mathematical, syntactical[2] or pragmatical[3] senses in which one may speak of information are not strictly relevant in this context and can be disregarded.

Over the last three decades, most analyses have supported a definition of *objective semantic information* (henceforth, the two specifications will be used sporadically, only for the sake of clarity) in terms of *data + meaning*. This bipartite account has gained sufficient consensus to become an operational standard in fields such as Information Science; Information Systems Theory, Methodology, Analysis and Design; Information (Systems) Management; Database Design; and Decision Theory, since these deal with data and information as reified entities.

A selection of quotations from a variety of influential texts can help to illustrate the popularity of the bipartite account:

> Information is data that has been processed into a form that is meaningful to the recipient (Davis and Olson, 1985: 200).
> Data is the raw material that is processed and refined to generate information. (Silver and Silver [1989], 6).
> Information equals data plus meaning (Checkland and Scholes [1990], 303).
> Information is data that have been interpreted and understood by the recipient of the message […] [a management information system is]… a system to convert data from internal and external sources into information. (Lucey [1991], 5 and 15)
> […] data will need to be interpreted or manipulated [to] become information. (Warner [1996], 1)

The bipartite account has begun to influence the philosophy of information and computing as well (see for example Mingers [1997], who relies on Checkland and Scholes [1990], and Floridi [1999]). Examples could easily be multiplied.[4]

A more rigorous formulation of the bipartite account can be provided using the terminology introduced by Devlin [1991]. He has suggested the symbol σ and the term "infon" to refer to discrete items of information, irrespective of their semiotic code and physical implementation:[5]

SDI σ qualifies as objective semantic information if and only if:

1. σ consists of a *non-empty* set (*D*) of data (d);
2. the data in *D* are *well-formed* (wfd);
3. the wfd in *D* are *meaningful* (mwfd = δ).

SDI requires a few clarifications.

According to SDI.1, *D* can contain *different types* of δ but it cannot be empty. Data can be of four types (Floridi [1999]):

δ.1) *primary data*. These are what we ordinarily mean by, and perceive as, the principal data stored in a database, e.g. a simple array of numbers, or the contents of books in a library. They are the data an information management system is generally designed to convey to the user in the first place;

δ.2) *metadata*. These data are secondary indications about the nature of the primary data δ.1. They enable a database management system to fulfil its tasks by describing essential properties of the primary data, e.g. location, format, updating, availability, copyright restrictions, etc.;

δ.3) *operational data*. A database management system may also monitor and collect data regarding usage of the database itself, the operations of the whole system and the system's performance;

δ.4) *derivative data*. These are data that can be extracted from (δ.1)-(δ.3), whenever the latter are used as sources in search of clues or inferential evidence, e.g. for comparative and quantitative analyses.

At first sight, the *typologically neutrality* TN of SDI may seem counterintuitive. A database query that returns no answer, for example, still provides some information, if only negative; and silence is a meaningful act of communication, if minimalist. TN cannot be justified by arguing that absence of data is usually uninteresting, because similar pragmatic considerations are at least controversial, as shown by the previous two examples, and in any case irrelevant, since in this context the analysis concerns only objective semantic information, not *interested information*.[6] Rather, TN is justified by the following principle of data-types reduction:

PDTR σ consists of a non-empty set (D) of data δ; if D seems empty and σ still seems to qualify as information, then

1. the absence of δ is only apparent because of the occurrence of some *negative* primary δ, so that D is not really empty; or
2. the qualification of σ as information consisting of an empty set of δ is misleading, since what really qualifies as information is not σ itself but some information μ concerning σ, constituted by meaningful non-primary data about σ.

Consider the two examples above. If a database query provides an answer, it will provide at least a *negative* answer, e.g. "no documents found", so PDTR.1 applies. If the database provides no answer, either it fails to provide any data at all, but then no specific information σ is available, or there is a way of monitoring or inferring the problems encountered by the database query to establish, for example, that it is running in a loop, but then PDTR.2 applies. In the second example, silence could be negative information, e.g. as implicit assent or denial, or it could carry some non-primary information μ, e.g. the person has not heard the question.

When apparent absence of δ is not reducible to the occurrence of negative primary δ, either there is no information or what becomes available and qualifies as information is some further information μ about σ constituted by some non-primary δ. Now, differences in the reduction both of the absence of positive primary δ to the presence of negative primary δ and of σ to μ (when D is truly empty) warrant that there can be more than one σ that may (misleadingly) appear to qualify as information and be equivalent to an apparently empty D. Not all silences are the same. However, since SDI.1 defines information in terms of δ, without any further restriction on the typological nature of the latter, it is sufficiently general to capture primary (positive or negative) δ and non-primary data as well, and hence the corresponding special classes of information just introduced.

According to SDI.1, σ can consist of a set containing only a single datum. Normally, information is conveyed by large clusters of well-formed, codified data, usually alphanumeric, which are heavily constrained syntactically and already very rich semantically. However, in its simplest form a datum can be reduced to just a lack of uniformity, i.e. a difference between the presence and the absence of e.g. a sign or a signal or a property:

Dd $$d = [x \quad y]$$

The twofold dependence of information on the occurrence of clusters of data and of data on the occurrence of differences physically implementable, explains why information is, in many cases, support-independent. Interpretations of this independence, however, can vary quite radically because Dd leaves open to further specification not only the logical type to which the relata belong (see TN), but also *the classification* of the relata (*taxonomical neutrality*) and *the kind of support* that may be required by the implementation of their inequality (*ontological neutrality*).

Let us consider the *taxonomical neutrality* first. It is usually the entity exhibiting the anomaly that is conveniently identified with the datum, for example because it is perceptually more conspicuous or less redundant than the background conditions. However, since the relation of inequality is symmetric, nothing is a datum by itself. Rather, being a datum is an external property. This taxonomical neutrality of SDI can be expressed thus:

TaxN a datum is a relational entity.

For example, low and high voltage are data only because of their mutual relation, and the white paper is not just a necessary background condition for the occurrence of the black dot as a datum, it is a constitutive part of the datum itself, together with the fundamental relation of inequality that couples it with the dot.

Consider next the *ontological neutrality*. Its importance becomes clear in light of three popular slogans in the literature on the philosophy of information and computing. SDI endorses the following modest thesis:

ON no information without representation.

Following Landauer [1987], [1991] and [1996] and Landauer and Bennett [1985], ON is often interpreted materialistically, as advocating the impossibility of physically disembodied information, through the equation "representation = physical implementation":

S.1 no information without physical implementation.

S.1 is an inevitable assumption when working on the physics of computation, since computer science must necessarily take into account the physical properties and limits of the carriers of information.[7] However, as shown by ON, SDI leaves unspecified whether ultimately the occurrence of every discrete state necessarily requires a material implementation of the data representations. Arguably, environments in which there are only noetic entities, properties and processes (e.g. Berkeley, Spinoza), or in which the material or extended universe has a noetic or non-extended matrix as its ontological foundation (e.g. Pythagoras, Plato, Leibniz, Fichte, Hegel), seem perfectly capable of upholding ON without embracing S.1. The relata in Dd could be monads, for example. This explains why SDI can also be consistent with two other popular slogans that, this time, are favourable to the proto-physical nature of information:

S.2 it from bit (this slogan has been coined by the physicist J. A. Wheeler [1989])

S.3 information is information, not matter or energy. No materialism which does not admit this can survive at the present day. (Wiener [1961], p.132).

S.2 endorses an information-theoretic, metaphysical monism: the universe's essential nature is computational or digital, being fundamentally composed of information instead of matter or energy, with material objects as complex secondary manifestation.[8] S.3 advocates a more pluralistic approach along similar lines. Both are compatible with SDI.

SDI.3 can be explained by discussing a fourth slogan:

S.4 In fact, what we mean by information - the elementary unit of information - is a difference which makes a difference (Bateson [1973], 428)

S.4 is one of the earliest and most popular[9] formulations of SDI. We have seen that a "difference" is just a discrete state, i.e. a datum, and "making a difference" means that the datum is "meaningful", at least potentially. How a data set D can acquire a semantics is one of the hardest problem in philosophy. Luckily, it needs not detain us here because SDI.3 only requires the δ in D to be already provided with a semantics. The point in question is not how but whether these δ can be correctly described as having a semantics *independently* of an interpreter or user. This can be referred to as the *genetical neutrality* of SDI:

GN δ in D have a semantics *independently* of an interpreter/user.

Before the discovery of the Rosetta Stone, the Egyptian hieroglyphics were already regarded as information, even if their semantics was beyond the comprehension of any interpreter or linguistic user. The discovery of an interface between Greek and Egyptian did not affect the hieroglyphics' embedded semantics but its accessibility. This is the weak, conditional-counterfactual sense in which SDI.3 speaks of meaningful data being embedded in a set of information-carriers *user*-independently. GN is to be distinguished from the stronger thesis, supported for example by Dretske [1981], according to which data could have their own semantics independently of an intelligent *producer*. In this case, the standard example is usually provided by the concentric rings visible on the wood of a cut tree trunk, which may be used to estimate the age of the plant.

3. Alethic Neutrality

Insofar as SDI provides *necessary* conditions for σ to qualify as information, we have seen that it also endorses four types of neutrality: TN, TaxN, ON and GN. These features represent an obvious advantage, as they make SDI perfectly scalable to more complex cases, and hence reasonably flexible in terms of applicability. However, by specifying that SDI.1-SDI.3 are also *sufficient* conditions, SDI further endorses a fifth type of *alethic neutrality*, and this turns out to be problematic.

According to SDI, δ are alethically flexible:

AN meaningful and well-formed data δ qualify as information no matter whether they represent a truth or a falsehood.

Alethic values are not embedded in, but supervene on information. It follows that:[10]

FI false information, i.e. misinformation, is a genuine type of information, not pseudo-information; and

TI "true" in "true information" is not redundant, i.e. it cannot be eliminated without semantic loss.

Neither consequence is ultimately defensible and the rejection of any of the two forces a revision of AN. For the sake of simplicity, in the rest of this article we shall pursue only the first strategy, i.e. the rejection of FI. We shall see that none of the main reasons that could be adduced to interpret false information as a type of information is convincing, whilst there are compelling reasons to treat it as pseudo-information. On the other hand, forceful arguments against TI can easily be imported from the literature on deflationary theories of truth (Ramsey [1927], Williams [1976], Horwich [1990], Kirkham [1992]). They are not be rehearsed here because the development of this strategy has further substantial consequences that deserve a full, independent analysis, and this lies beyond the scope of this paper. I shall return on the issue in the conclusion, but only to clarify what may be expected from this line of reasoning.

4. Is False Information a Type of Information?

Linguistically, the expression "false information" is common and perfectly acceptable. What is meant by it is less clear. An enlightening example is provided by the American legislation on food disparagement.

Food disparagement is legally defined in the US as the wilful or malicious dissemination to the public, in any manner, of *false information* that a perishable food product or commodity is not safe for human consumption. "False information" is then defined, rather vaguely, as

- "information not based on reasonable and reliable scientific inquiry, facts, or data" (e.g. Ohio, http://www.ohiocitizen.org/campaigns/pesticides/veglibel.html);
- "information that is not based on verifiable fact or on reliable scientific data or evidence" (e.g. Vermont, http://www.leg.state.vt.us/docs/2000/bills/intro/h-190.htm);
- "information which is not based on reliable, scientific facts and reliable scientific data which the disseminator knows or should have known to be false" (e.g. Arkansas, http://www.arkleg.state.ar.us/ftproot/bills/1999/htm/hb1938.htm).

In each case, false information is defined in the same way in which one could define a rotten apple, i.e. as if it were a "bad" type of information, vitiated by some shortcoming. This common mistake can be variously explained.

Suppose that there are going to be *exactly two* guests for dinner tonight, one of whom is vegetarian (S). Let the false information about the situation S be FI = "(A) there will be *exactly three* guests for dinner tonight and (B) one of them is vegetarian". One may wish to argue that FI is not mere pseudo-information, but a certain type of information that happens to be false, because:
FI.1) FI can include genuine information.

Reply: this merely shows that FI is a compound in which only B, which is *true*, qualifies as information, whilst A, being *false*, does not.

FI.2) FI can entail genuine information.

Similar reply: even if we correctly infer only some semantically relevant and true information TI from FI, e.g. that "there will be more than one guest", what now counts as information is the inferred *true* consequence TI, not FI.

FI.3) FI can still be genuinely informative, if only indirectly.

Reply: this is vague, but it can be reduced to the precise concept of information μ constituted by non-primary data, already discussed in section two. For example, FI may be coupled to some true, metainformation M that the source of FI is not fully reliable. What now counts as information is the true M, not the false FI.

FI.4) FI can support decision-making processes.

Reply: we could certainly cook enough food on the basis of FI but this is only accidental. The actual situation S may be represented by a wedding dinner for a hundred people. That is why FI fails to qualify as information. However, FI.4 clarifies that, if FI is embedded in a context in which there is enough genuine metainformation about its margins of error, then FI can be more *useful* than both a false FI_1, e.g. "there will be only one guest for dinner", and a true but too vacuous FI_2, e.g. "there will be less than a thousand guests for dinner". What this shows is not that false information is an alethically qualified type of genuine information but that, *pragmatically*, false information can still be *interesting* (in the technical sense of the expression, see the concept of *interested information* in section two) because sources of information are usually supposed to be truth-oriented or truth-tracking by default (if the are mistaken, they are initially supposed to be mistaken only accidentally and minimally), and that, *logically*, an analysis of the information content of σ must take into account the level of approximation of σ to its reference, both when σ is true and when it is false.

FI.5) FI is meaningful and has the same logical structure of genuine information.

Reply: this is simply misleading. Consider the following FI: "One day we shall discover the biggest of all natural numbers". Being necessarily false, this can hardly qualify as genuine but false information. It can only provide some genuine information μ, e.g. about the mathematical naivety of the source. In the same sense in which hieroglyphics qualified as information even when they were not yet interpretable, vice versa, an infon σ does not qualify as information just because it is interpretable.

FI.6) FI could have been genuine information had the relevant situation being different. Perhaps the difficulty seen in FI.5 is caused by the necessary falsehood of the example discussed. Meaningful and well-formed data that are only contingently false represent a different case and could still qualify as a type of information. It only happens that there will be less guests than predicted by FI. FI is a type of information because S could have been otherwise.

Reply: this only shows that we are ready to treat FI as quasi-information in a hypothetical-counterfactual sense, which is just to say that, if S had been different then FI would have been true and hence it would have qualified as information. Since S is not, FI does not. FI needs not be *necessarily* pseudo-information. It may be *contingently* so.

5. False Information is Pseudo-information

The confusion about the nature of false information seems to be generated by a misleading analogy. The most typical case of misinformation is a false proposition. Now a false proposition is still a proposition although it is further qualified as not being true. Likewise, one may think that misinformation is still a type of information, although it happens to be untrue. The logical confusion here is between attributive and predicative uses of "false". The distinction was already known to medieval logicians, it was revived by Geach [1956] and requires a further refinement before being applied.

Take two adjectives like "male" and "good". A male constable is a person who is both male and employed as a policeman. A good constable, however, is not a good person who is also employed as a member of the police force, but rather a person who performs well all the duties of a constable. "Male" is being used as a *predicative* adjective, whereas "good" modifies "constable" and is being used as an *attributive* adjective. If an adjective in a compound is attributive, the latter cannot be split up. This indivisibility property means that we cannot safely predicate of an attributively-modified x what we predicate of an x. So far Geach. We now need to introduce two further refinements. Peace Geach, at least some adjectives can be used *attributively* or *predicatively* depending on the context, rather than being necessarily classified as either attributive or predicative intrinsically. Secondly, the attributive use can be either positive or negative. Positive attributively-used adjectives further qualify their reference x as y. "Good constable" is a clear example. Negative, attributively-used adjectives negate one or more of the qualities necessary for x to be x. They can be treated as logically equivalent to "not". For example, a false constable (attributive use) is clearly not a specific type of constable, but not a constable at all (negative use), although the person pretending to be a constable may successfully perform all the duties of a genuine constable (this further explains FI.4 above). The same holds true for other examples such as "forged banknote", "counterfeit signature", "false alarm" and so on.

We can now return to the problem raised by the analogy between a false proposition and false information. When we say that P, e.g. "the earth has two moons", is false, we are using "false" predicatively. The test is that the compound can be split into "P is a proposition" and "P is a contingent falsehood". On the contrary, when we also describe it as false information, we are using "false" attributively, to negate the fact that P qualifies as information at all. The test is that, as in the case of the false constable, the compound cannot be split: it is not the case that P constitutes information about the number of natural satellites orbiting around the earth and is also a falsehood. Compare this case to the one in which we qualify σ as digital information. This obviously splits into "σ is information" and "σ is digital".

6. The Standard Definition of Information Revised

Well-formed and meaningful data that are incorrect, imprecise, inaccurate, or somehow vitiated by errors are mere misinformation. We have seen that misinformation (false information) is not a type of information but rather pseudo-information. As Dretske and Grice put it:

> […] *false* information and *mis*-information are not kinds of information – any more than decoy ducks and rubber ducks are kinds of ducks (Dretske [1981], 45)

> False information is not an inferior kind of information; it just is not information. (Grice [1989], 371)

"False information" is not an oxymoron, but a way to specify that the contents in question do not correspond to the situation x they purport to represent. Syntactical well-formedness and meaningfulness are necessary but insufficient conditions for information. This is why to exchange (receive, sell, buy, etc.) false information about x, e.g. about the number of moons orbiting around the earth, is to exchange no information at all about x, only meaningful and well-formed data. It follows that SDI needs to be modified, to include a fourth condition about the truthful nature of the data in question, thus:

RSDI σ qualifies as objective semantic information if and only if:

1. σ consists of a *non-empty* set (*D*) of data (d);
2. the data in *D* are *well-formed* (wfd);
3. the wfd in *D* are *meaningful* (mwfd = δ);
4. the δ in *D* are *truthful.*

7. Conclusion: summary of results and future developments

In this paper, the standard definition of objective semantic information (SDI) has been criticised for providing necessary but insufficient conditions for the qualification of data as information. The definition has been modified to take into account the objection that information encapsulates truth, and hence that false information merely fails to qualify as information at all. The new version of the definition (RSDI) now describes information as truthful, meaningful and well-formed data. In the course of the analysis, the paper has provided an explanation and refinement of the three necessary conditions established by SDI; an analysis of the concept of data; and a clarification of four popular interpretations of SDI. Three results of great conceptual interest, based on RSDI, have been left to a second stage of this research:

1) a critique of the deflationary theories of truth. From RSDI, it follows that one can accept deflationary arguments as perfectly correct while rejecting the validity of a deflationary theory of truth. "True" in "true information" is redundant because there cannot be information that is not true, but deflationary theories of truth mistake this linguistic or conceptual redundancy for unqualified dispensability, whilst "true" is redundant only because information encapsulates truth.
2) the analysis of the definition of knowledge in light of a "continuum" hypothesis that knowledge encapsulates truth because it encapsulates objective semantic information.
3) the development of a quantitative theory of semantic information based on truth-values and degrees of discrepancy of σ with respect to a given situation rather than probability distributions (Bar-Hillel and Carnap [1953]).

Notes

[1] For some reviews of the variety of meanings and corresponding different theoretical positions, see Braman [1989], Losee [1997], Machlup [1983], NATO [1974, 1975, 1983], Schrader [1984], Wellisch [1972], Wersig and Neveling [1975].
[2] Syntactic information is studied by the Statistical Theory of Signals Transmission (STST), also known as Mathematical Theory of Information, Communication Theory, Information Theory and Mathematical Information Theory. Two of the best conceptual introductions to STST are still Cherry [1978] and Dretske [1981]. More technical presentations are found in Reza [1994] and Van der Lubbe [1997], the classic references are collected in Shannon [1993].
[3] See Bar-Hillel and Carnap [1953]. A pragmatic theory of information addresses the question of how much information a certain message carries for a subject S in a given doxastic state and within a specific informational environment.
[4] Many other sources endorse equivalent accounts as uncontroversial. See for example Bell and Wood-Harper [1998]; Burch and Grudnitski [1989]; Drucker [1990]; Galliers [1987]; Kock, McQueen and Corner [1997]; Schoderbek, Schoderbek and Kefalas [1990]; Schultheis and Sumner [1998]; Whittemore and Yovits [1973].
[5] This is in line with common practice in AI, Computer Science and ICT (information and communication technology), where the expression "information resources" is used to refer to objective semantic information in different formats, e.g. printed or digital texts, sound or multimedia files, graphics, maps, tabular data etc. (Heck and Murtagh [1993]).
[6] *Interested information* is a technical expression. The pragmatic theory of interested information is crucial in Decision Theory, where a standard quantitative axiom states that, in an ideal context and *ceteris paribus*, the more informative σ is to S, the more S ought to be rationally willing to pay to find out whether σ is true (Sneed [1967]).
[7] Landauer and Bennett [1985], Landauer [1987]. The debate on S.1 has flourished especially in the context of quantum computing, see Landauer [1991] and Deutsch [1985], [1997]; Steane [1998] provides a review.
[8] A similar position has been defended more recently in physics by Frieden [1998], whose work is based on an Platonist perspective.
[9] See for example Franklin [1995], 34 and Chalmers [1996], 281.
[10] Note that the conjunction of FI and TI presupposes two theses usually uncontroversial: (a) that information is strictly connected with, and can be discussed in terms of truth and falsehood; and (b) that any theory of truth should treat alethic values or concepts symmetrically.

References

Bar-Hillel Y. 1964, *Language and Information* (Reading, Mass.; London: Addison-Wesley).
Bar-Hillel Y. and Carnap R. 1953, "An Outline of a Theory of Semantic Information", rep. in Bar-Hillel [1964], pp. 221-274, page references are to this edition.

Bateson, G. (1973), *Steps to an Ecology of Mind* (Paladin. Frogmore, St. Albans).
Bell, S. and Wood-Harper, A. T. 1998, *Rapid Information Systems Development: Systems Analysis and Systems Design in an Imperfect World*, 2nd ed. (Maidenhead: McGraw Hill).
Braman, S. 1989, "Defining Information". *Telecommunications Policy* 13, 233-242.
Buckland, M. (1991), "Information as Thing", *Journal of the American Society of Information Science* (42.5), 351-360.
Burch, J. and Grudnitski, G. 1989, *Information Systems: Theory and Practice*, 5th ed. (New York: John Wiley).
Checkland P. B. and Scholes J. (1990), *Soft Systems Methodology in Action* (New York: John Wiley & Sons).
Cherrry C. 1978, *On Human Communication* 3rd ed. (Cambridge, Ma: MIT Press).
Davis, G. B. and Olson M. H. (1985), *Management Information Systems: Conceptual Foundations, Structure, and Development*, 2nd ed. (New York: McGraw-Hill).
Deutsch D. (1985), "Quantum theory, the Church-Turing Principle and the Universal Quantum Computer" *Proceedings of the Royal Society*, 400, 97-117.
Deutsch D. (1997). *The Fabric of Reality* (London: Penguin).
Devlin K. (1991), *Logic and Information* (Cambridge: Cambridge University Press).
Dretske F. 1981, *Knowledge and the Flow of Information* (Cambridge, Ma: MIT Press, rep. Stanford: CSLI, 1999).
Drucker P. 1990, *The New Realities* (London: Mandarin).
Floridi L. 1999, *Philosophy and Computing – An Introduction* (London – New York: Routledge).
Franklin S. 1995, *Artificial Minds* (Cambridge, Mass.: The MIT Press).
Frieden B. R. 1998, *Physics from Fisher Information: a Unification* (Cambridge: Cambridge University Press).
Galliers R. (ed.) 1987, *Information Analysis: Selected Readings* (Wokingham: Addison Wesley).
Geach P. T. 1956, "Good and Evil", *Analysis* 17, 33-42.
Grice P. 1989, *Studies in the Way of Words* (Cambridge Mass.: Harvard University Press).
Heck A. and Murtagh F. (eds.) 1993, *Intelligent Information Retrieval: the Case of Astronomy and Related Space Sciences* (Dordrecht - London: Kluwer Academic).
Horwich P. 1990, *Truth* (Oxford: Blackwell).
Kirkham R. L. 1992, *Theories of Truth: A Critical Introduction* (Cambridge, Mass.: MIT Press).
Kock, N. F., Jr., McQueen, R. J. and Corner, J. L. 1997, "The Nature of Data, Information and Knowledge Exchanges in Business Processes: Implications for Process Improvement and Organizational Learning", *The Learning Organization*, 4 (2): 70-80.
Landauer R. and Bennett C. H. (1985), "The Fundamental Physical Limits of Computation", *Scientific American* (July), 48-56.
Landauer R. (1987), "Computation: A Fundamental Physical View", *Physica Scripta* 35, 88-95.
Landauer R. (1991), "Information is Physical'", *Physics Today* 44, 23-29.

Landauer R. (1996), “The Physical Nature of Information” *Physics Letter* (A 217), 188.
Losee R. M. 1997, “A Discipline Independent Definition of Information”, *Journal of the American Society for Information Science*, 48.3, 254-269.
Lucey, T. (1991), *Management Information Systems*, 6th ed. (London: DP Publications Ltd).
Machlup F. 1983, “Semantic Quirks in Studies of Information”, in Machlup, F. and Mansfield, U. eds. (1983). *The Study of Information: Interdisciplinary Messages*, pp. 641-671 (New York: John Wiley).
Mingers J. 1997, “The Nature of Information and Its Relationship to Meaning”, in Winder *et al.* (1997), pp. 73-84.
NATO Advanced Study Institute in Information Science, Aberystwyth, 1974. (1975) *Perspectives in Information Science*, ed. by A. Debons and W. J. Cameron. (Leiden: Noordhoff).
NATO Advanced Study Institute in Information Science, Champion, 1972. (1974). *Information Science: Search for Identity*, ed. by A. Debons (New York: Marcel Dekker).
NATO Advanced Study Institute in Information Science, Crete, 1978. (1983). *Information Science in Action: Systems Design*, ed. by A. Debons and A. G. Larson. (Boston: Martinus Nijhoff).
Ramsey F. P. 1927, ‘Facts and Propositions’, Proceedings of the Aristotelian Society supplement to 7: 153-70.
Reza F. M. 1994, *An Introduction to Information Theory* (New York: Dover, orig. 1961).
Schoderbek, C. G., Schoderbek, P. P. and Kefalas, A.G. 1990, *Management Systems: Conceptual Considerations*, 4th ed. (Homewood, IL: BPI/Irwin).
Schrader A. 1984, “In Search of a Name: Information Science and its Conceptual Antecedents”, *Library and Information Science Research* 6, 227-271.
Schultheis R. and Sumner M. 1998, *Management Information Systems: The Manager's View,* b 4th ed. (London: McGraw-Hill).
Shannon C. E. 1993, *Collected Papers* ed. by N. J. A. Sloane and & A. D. Wyner (Los Alamos, Ca: IEEE Computer Society Press).
Silver, G. A. and Silver, M. L. (1989), *Systems Analysis and Design* (Reading, MA: Addison Wesley).
Sneed D. J. 1967, “Entropy, Information and Decision”, *Synthese* (17), pp. 392-407.
Steane A. M. (1998) “Quantum Computing”, *Reports on Progress in Physics*, 61, 117-173. This review article is also available online at http://xxx.lanl.gov/abs/quant-ph/9708022
Szaniawski K. 1984, “On Defining Information”, now in Szaniawski [1998].
Szaniawski K. 1998, *On Science, Inference, Information and Decision Making, Selected Essays in the Philosophy of Science*, ed. by A. Chmielewski and J. Wolenski (Dordrecht: Kluwer).
Van der Lubbe J. C. A. 1997, *Information Theory* (Cambridge: Cambridge U.P., orig. 1988).
Warner, T. (1996), *Communication Skills for Information Systems* (London: Pitman Publishing).

Wellisch H. 1972, "From Information Science to Informatics", *Journal of Librarianship* 4, 157-187.
Wersig, G. and Neveling, U. 1975, "The Phenomena of Interest to Information Science", *Information Scientist* 9, 127-140.
Wheeler J. A. (1989), "It from Bit", *Proceedings of the 3rd International Symposium on Foundations of Quantum Mechanics*, Tokyo.
Whittemore B. J. and Yovits M. C. 1973, "A generalized conceptual development for the analysis and flow of information" *Journal of the American Society for Information Science*, 24 (3): 221-231.
Wiener N. (1961), *Cybernetics or Control and Communication in the Animal and the Machine*, 2nd ed. (Cambridge, Mass.: MIT Press).
Williams C. J. F. 1976, *What is Truth?* (Cambridge: Cambridge University Press).
Winder R. L., Probert S. K. and Beeson I. A. (1997), *Philosophical Aspects of Information Systems* (London: Taylor and Francis).
Chalmers, D. J. 1997, *The Conscious Mind: in Search of a Fundamental Theory* (Oxford: Oxford University Press).