An Evaluation of Theories of Information with Regard to the Semantic and Pragmatic Aspects of Information Systems

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It is argued here that the discipline of information systems does not have a clear and substantive conceptualization of its most fundamental category, namely, information itself. As a first stage in addressing the problem, this paper evaluates a wide range of theories or concepts of information in order to assess their suitability as a basis for information systems. Particular importance is placed on the extent to which they deal with the semantic and pragmatic dimensions of information and its relation to meaning. It is concluded that Dretske's analysis of knowledge and information provides the most suitable basis for further development.

1. INTRODUCTION

Information systems could not, presumably, exist without information, and yet within information systems as a discipline there is little agreement over the nature of information. As Lewis (1991) and Dretske (1981) point out, few books concerning information systems actually define the concept of information clearly.[2] Broadly, two views of information can be discerned. The most common suggestion is that information is data that has been processed in some way to make it useful. Philosophically, this involves an implicit assumption that data and information are objective, that is, independent entities with their own structures. An alternative view emphasises the subjective nature of information—the idea that different observers may generate different information from the same data given their differing values, beliefs, and expectations (Lewis, 1993).

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[2] One of the few IS textbooks that seriously addresses the nature of information is that by Liebenau and Backhouse (1990).

Checkland (Checkland and Scholes, 1990, p. 303) formulates this view as *"information equals data plus meaning."* That is, by attributing meaning to data, we create information. The problem with the latter formulation is that the terms and their relations are not precisely and clearly defined. Thus what are *data*, *meaning*, and *information*, and how exactly do meaning and data interact to produce information?

Despite this absence of agreement about the discipline's foundation, there is relatively little discussion about the subject within the IS literature. This is in contrast to related disciplines such as information *science* (and to some extent philosophy), where a variety of theories of information has been strongly debated. The purpose of this paper is to review and evaluate a range of information theories in terms of the extent to which they could serve as a basis for the discipline of information systems at both the semantic and the pragmatic levels. The most promising approach, which is found to be that of Dretske (1981),[3] forms the basis of later work by Mingers (1995b), who integrates it with Maturana's (1975, 1978; Maturana and Varela, 1980) theory of cognition and Habermas' (1979, 1984, 1989) theory of communicative action.

2. ORIENTATION

Before embarking on such an evaluation, it is perhaps necessary to make explicit the author's particular orientation towards this task.

First, it has been argued, for example by Goffman (1970) and Gilligan (1994), that the term "information" is used in so many different ways and contexts that it is not worthwhile trying to produce a single conceptualization commanding general agreement. While I accept that "information" has, as a matter of fact, been used multifariously, I do not think that this precludes the *possibility* of developing a more rigorous and coherent definition. And, I would argue, if information systems is to become (I do not think it yet is) a properly founded discipline, then it must make just such an attempt to clarify its fundamental concepts.

Second, in general terms information systems are concerned with processes of symbolic communication and must therefore rest on the ideas of semiotics. A core idea is the semiotic framework (Morris, 1938; Stamper, 1973, 1985, 1987), which characterizes a number of different levels of interest: *empirics*—the study of signal properties and transmission; *syntactics*—the study of the formal properties of systems of signs; *semantics*—the study of the meaning of signs; and *pragmatics*—the study of the use of signs. Within these terms, many theories of information, drawing on Shannon's (Shannon and Weaver, 1949)

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[3] Anderton (1987) also proposes Dretske's work as providing a suitable basis for information systems.

information theory, concern only the levels of empirics or syntactics. To be of relevance to information systems in practice, however, any theory of information must be able to address the semantic and pragmatic aspects of information as it is actually used, unrestrictedly, within systems of human activity.

Third, I accept broadly the interpretivist critique of objectivism—that is, that social actions are fundamentally different from physicochemical interactions in being inherently *meaningful*, and are thus dependent partly on the actor's culture, language, and historical situation. This implies that any account of *information* must also deal explicitly with its relationship to *meaning*—their distinction (if there is one) and their interaction (Boland, 1987). My limited acceptance of interpretivism does not mean that I think all phenomena are a construction of the observer. Ontologically, I hold that there are physical and social structures with independent existence even though epistemologically we have no pure, unmediated access to them. In particular, language and other social practices, and therefore some aspects of meaning, are not individually subjective but *intersubjective*—that is, based on a preexisting understanding among particular groups of people.

Theoretically, my approach at the *semantic* level is informed by Maturana and Varela's (Maturana, 1975, 1978, 1988; Maturana and Varela, 1980, 1987) biologically based theories of cognition and language founded on their underlying concept of autopoiesis. These provide a biological explanation for cognition and language showing that it is inevitably subject-dependent. These ideas have also been explored in the context of information systems by Winograd and Flores (1986), Winograd (1987), Harnden and Mullery (1991), Stephens and Wood (1991), and Kensing and Winograd (1991).

At the *pragmatic* level, the work of Habermas (1979, pp. 1–68, 1984, pp. 273–338) on what he calls "universal pragmatics"[4] will be employed at the next stage of the research. Habermas aims to formalise the analysis of language *in use*—that is, active utterances aimed at understanding and agreement rather than simple sentences or propositions. His work has already provided a number of ideas for conceptualising information systems, generally referred to as the "language-action approach," for example, Goldkuhl and Lyytinen (1982, 1984), Lyytinen and Klein (1985), Lehtinen and Lyytinen (1986), Ngwenyama (1991), and Lyytinen *et al.* (1991).

3. EVALUATION CRITERIA

In order to evaluate a range of information concepts[5] it is clearly necessary to have a set of criteria of some kind (Belkin, 1978). As we shall see, the great

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[4] More recently, Habermas uses the general term "communicative action."
[5] I shall use the terms information theory and information concept synonymously.

diversity of approaches to be considered means that the criteria used will have to be very broad and the evaluation qualitative rather than quantitative, but it is still important to make them explicit. I shall outline four in descending order of importance.

The first criterion is the generality of the theory or concept—the range of situations that it covers. One aspect, mentioned above, is that the concept should be usable at both the semantic and the pragmatic levels of communication, not merely the empiric or syntactic. The other is that it should apply to all situations in which information may be relevant—that is, the full range of signs and symbols. Some theories deal only with linguistic expressions and conscious communication, but it seems clear that information is potentially associated with nonlinguistic behaviour such as gestures and expressions; with symbols such as maps or Windows icons; and with physical events, for example, a door bell ringing, rain clouds gathering, or an item of stock being missing. Mingers (1995b) provides a typology of these different semiotic levels that is reproduced in Fig. 1.

The second criterion is that the concept should be useful and appropriate for the discipline of information systems. I will use Belkin's (1978) categorization of three types of requirements—definitional, behavioural, and methodological—although differing in my interpretation of these. The definitional requirements are that the concept employed should provide a clear and unambiguous characterization of the nature of information and its ontological status, and that it should enable ''information'' clearly to be distinguished from related terms such as ''data'' and ''meaning.'' The behavioural requirement is that the concept must reflect the observed behaviour of people involved with the production or use of information systems. That is, it should be capable of dealing with the real world of information systems in use rather than some abstracted or formalised aspects of it. An implication of this requirement is that an adequate concept of information must recognise that information systems form part of systems of social activity and communications, and so must allow for the (partly) interpreted and negotiated nature of social reality, accepting that signs and symbols are always open to multiple interpretations by different observers and in different contexts. The methodological requirement is that the concept should be useful or usable for the tasks of information systems as a discipline. It should contribute towards the understanding and development of more effective information systems.

The third criterion concerns integration with other disciplines. Clearly information (and meaning) are transdisciplinary concepts—they are also the concern of semiotics, social theory, and philosophy, for example—and so conceptualizations that integrate well with such disciplines are to be preferred to those which go against or ignore theory in these other areas. This is obviously a

Cause → Event

Connotation →

Signification ← Symbol → Import

Indirect link - consensual
map symbols
toilet sign
numbers (data)

Signification → Sign → Import

Generator   A (direct) trace   Implications
bear   bear print   get away
person   knock on door   "the postman"
children   toys left out   kids were here

Connotation →

Signification ← Utterance → Import

Intent

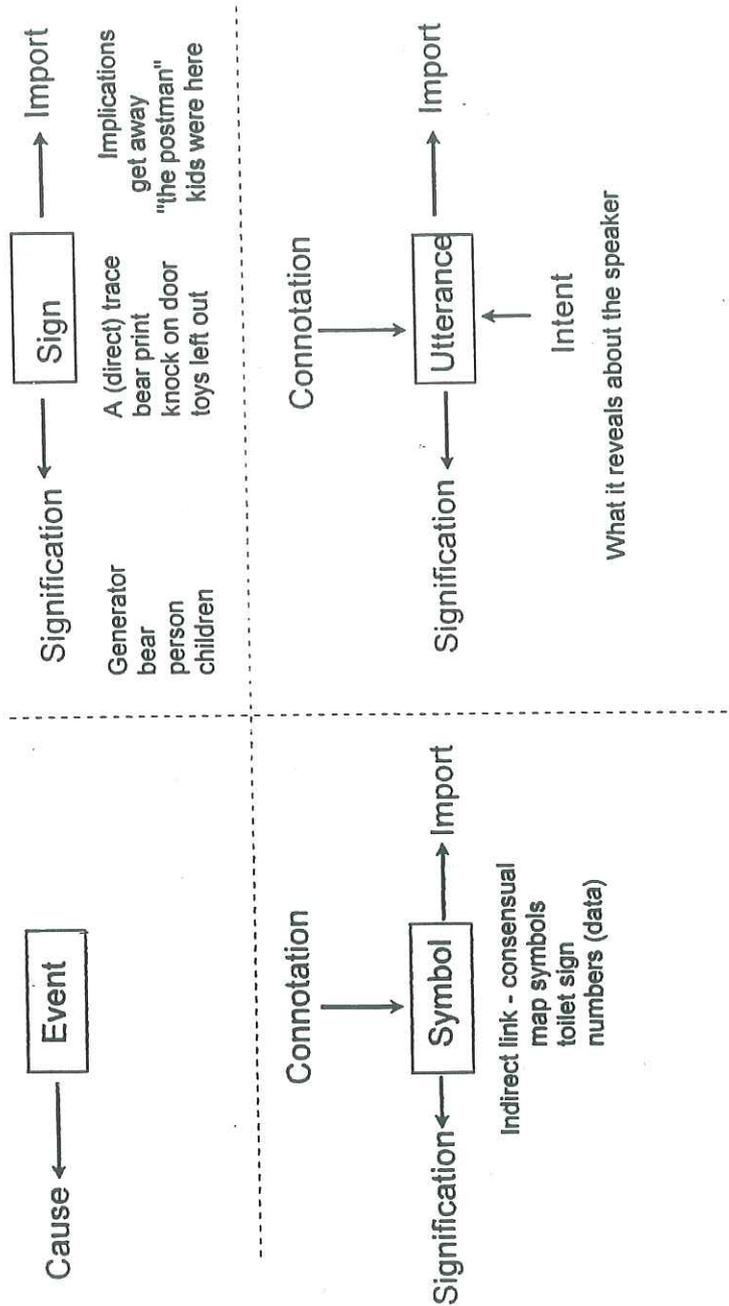What it reveals about the speaker

Fig. 1. A typology of signifiers.

complex question as these other disciplines are themselves fragmented with competing theoretical stances, but even so, a particular conception of information is stronger the less isolated it is.

Finally, and of lesser importance, is the extent to which a particular concept of information matches our daily, commonsense usage of the term. If other criteria are equivalent, it would seem better to adopt a theory which fits in with our intuitive notions than one which does not. For instance, some theories maintain that information is the change in expectations in a particular person caused by a particular message. In this interpretation, reference books and railway timetables contain *no* information at all except when they are read, and then only in the head of the reader. Derr (1985) has produced an analysis of the concept of information as used in ordinary language.

4. AN EVALUATION OF SELECTED THEORIES OF INFORMATION

4.1. Overview

There are a considerable number of different information theories or concepts and we will not be able to cover them all. But it is possible to group them and to consider the most important or typical from each category. The major grouping in fact consists of those which derive in some way from Shannon and Weaver's (1949) information theory but it is the subgroups within this category which are of importance. These reflect different ways of extending the theory to a theory of *semantic* information, that is, recognising the importance of meaning and that information and meaning are ultimately relative to the interpretation of the receiver.

4.2. Shannon and Weaver's Information Theory

Shannon and Weaver were engineers concerned with the correct transmission of messages. They developed a formula (based on earlier work by Hartley, 1928) for measuring the *amount* of information that a particular message might contain, but their theory said nothing about the *content* or *meaning* of a message, as they made clear:

> The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another. Frequently the messages have *meaning* . . . . These semantic aspects of communication are irrelevent to the engineering problem. The significant aspect is that the actual message is one *selected from a set of possible messages*. (Shannon and Weaver, 1949, p. 31)

Thus information theory is like measuring the volume of a container without knowing what it contains. Despite this, their work has formed the basis for the

majority of attempts to generate a theory of semantic information. Their central idea is that the amount of information conveyed by a symbol or message is inversely proportional to the probability of occurrence of that particular message. The more unlikely it is, the more information it carries. The message "the prime minister is dead" is much less likely than "the prime minister is alive" and so carries more information. A two-digit code in binary can carry less information than one in decimal since any particular message would be 1 of only 4 possibilities, as opposed to 1 of 100. Thus the amount of information available from a particular source depends on the number of possible messages that it could generate and the relative probabilities of the different messages. Another perspective is that the receipt of a message could be said to remove uncertainty from the receiver, and the greater the uncertainty, the greater the amount of information conveyed. Mathematical formulae were produced to measure this quantity of information.[6]

In some ways this is an intuitively appealing idea. If you were to learn in advance the result of a horse race, then the more horses in the race and the more evenly matched they were (and thus the more evenly the odds were spread), the greater the amount or value of the information to you. If there were only one horse in the race, the result would carry *no* information, as there would be no uncertainty. On the other hand, the concept suggests that a series of randomly chosen letters or words carries *more* information than messages in English since they are inherently more uncertain or unlikely than the patterned and structured linguistic messages. This information theory thus deals only with the observed statistical frequencies of occurrence of particular signs or messages.

In terms of the evaluation criteria, information theory fares badly. While it does provide a clear definition, it does not attempt to address the semantic or pragmatic aspects of information at all, nor does it deal with information as it is used within social action, subject to differing interpretations. We shall now consider a number of adaptions of this basic idea to overcome some of these limitations.

4.2.1. Bar-Hillel and Carnap's "Semantic Information"

Bar-Hillel and Carnap (1952; Bar-Hillel, 1952, 1955, 1964) claim that they can define and measure *semantic* information. They recognise at the outset that they do not deal with information in the communicational sense or pragmatic sense—i.e., how it is actually used by or between particular people (Bar-Hillel,

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[6] If a source can produce n possible, equally likely, messages, then the probability of occurrence of any one is $1/n$. The amount of information it can carry is $-\log_2(1/n)$, and the amount of information of the source is $-\Sigma(1/n)\log_2(1/n)$. Thus a source generating randomly a single digit produces $(10/10) \log_2(1/10) = 3.32$ bits of information. A source generating randomly a character from the English alphabet produces $(26/26) \log_2(1/26) = 4.70$ bits. If the messages are not equally likely, the formula incorporates the actual (theoretical or empirical) probabilities: $\Sigma(1/p_i)\log_2(1/p_i)$.

1964, pp. 398–399). Nor do they consider anything but propositional statements—other types and forms of signs are excluded.

Put very briefly, the theory is as follows. Imagine a universe in which there are entities, predicates (i.e., attributes or characteristics) which can be applied to the entities, and the logical connectives. *Basic statements* apply a predicate to an entity ("Adam has red hair"). *Ordinary statements* are combinations of basic statements ("Adam has red hair and Eve is young"). A *state description* is a complete description of the universe, that is, a statement describing every entity in terms of every predicate! Clearly, the number of possible state descriptions is extremely large. If we take a particular ordinary statement then there will be a number of state descriptions which it will exclude, i.e., which it will make false. It is precisely this which is the content or information conveyed by a statement.

The more states of the universe which are made impossible, the more content that the statement has. Analytical statements (true by definition) rule out nothing and so have zero content. Self-contradictory statements rule out everything and so have maximum content. Synthetic statement (which are *logically* indeterminate) rule out some possible states and so have some level of content. Generally, the more particular a statement becomes the more it rules out and so the greater its content. The inverse of content is *range*—that is, the set of state descriptions which imply the statement in question. The more particular a statement, the fewer state descriptions that will imply it and so the smaller its range.

The next step it to create a way of measuring information. This is based on Carnap's idea of *logical probability*, together with the principle that the more probable a statement the less information that it conveys. A statement is implied by all the state descriptions in its range. If the probability of each of these can be measured then the probability of the statement is given by the sum of the individual probabilities. Knowing the probability of a statement, the content (or measure of information) can be defined as an inverse function of the probability.[7]

The only remaining step is calculating the probabilities of the state descriptions in the first place. Various possibilities have been considered (see Stamper, 1973, pp. 258–263). It would be possible to derive the probabilities from the real world using relative frequencies or subjective probabilities. However, Carnap defines a concept of *logical* probability which is simply a function of the number and type of logical state descriptions. The simplest is just to make each state description equiprobable. Then the probability of each is simply the recip-

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[7] A number of such functions exist. For example, if $m(i)$ is the logical probability of statement i, then the content of the statement is $cont(i) = 1 - m(i)$, or a measure of its information is $inf(i) = \log 1/m(i)$ [$= -\log m(i)$].

rocal of the number that there are. Using this metric, the logical probability of a statement is merely the proportion of state descriptions which imply it.

There are a number of limitations of this approach insofar as it claims to be a definition of *semantic* information.

(i) In terms of generality it is limited to only restricted formal systems and linguistic propositions. It is hopelessly unrealistic and impractical for real-world languages and domains. To actually use it would involve calculating all the possible state descriptions for a universe with a large (possibly infinite) number of entities and characteristic and then being able to logically deduce which are or are not implied by any particular statement. This is out of the question even in an information system where the domains may be limited. Nor does it deal with anything other than formal propositions, and it is not easy to see how it could be developed to deal with other types of speech, let alone other meaningful signs and symbols and gestures.

(ii) While it provides a clear definition, it does not deal with the practical aspects of information use. The probabilities, and therefore the amount of information, are defined purely in terms of the number of possible state descriptions. It ignores the relative likelihood of these in the real world. For example, red-headed people may be relatively uncommon. It also ignores interconnections between predicates. Thus only old people may be susceptible to particular diseases. In some ways the approach is similar to Shannon's, although at a different level. That is it tries to measure the *possible* meanings of a proposition or set of propositions, rather than the *actual* meanings. Overall, it is more appropriately seen as a theory of *syntactic* information than of *semantic* information.

(iii) As admitted (Bar-Hillel, 1964, p. 298), the theory does not deal with meaning or interpretation for a particular person, given what they already know or what they intended, or communication of meaning between people. Thus, does "Adam has red hair" convey any information for someone who already knows that? Does a book in Chinese carry information for someone who does not speak Chinese? The theory assumes that propositions in themselves can convey information/meaning in some absolute sense completely independently of the receiver. Even Bar-Hillel and Carnap recognise that their theory assumes an "ideal receiver" (Bar-Hillel, 1964, p. 221). That is, a receiver with a perfect memory who understands all of logic and mathematics and can deduce the logical consequences of any sentence.

4.2.2. *Jumarie's Concept of Relative Information*

Jumarie (1990) is explicitly concerned develop Shannon's theory to the semantic level and take into account the observer or receiver of information.

> . . . It should be possible to derive a theory of information which explicitly takes account of the viewpoint of the observer, and . . . is consistent with the mathematical theory of communication as initiated by Shannon. (Jumarie, 1990, p. xi)

Jumarie interprets Shannon's theory of information in terms of entropy.[8] We start with a source which can, probabilistically, produce various outcomes. These may be symbols, words, or sentences, for example. The source can be seen to generate a certain amount of information or entropy. As discussed above, this deals only with the statistical properties of the symbols, not with their meaning. Jumarie refers to this as *syntactic entropy*.[9] However, when these symbols, let's say words, are received by an observer they will have a meaning for that observer. Rather, each word may well have a range of possible meanings depending on the observer and the context. This range of meanings generates a second source of information or entropy—*semantic entropy*. Adding the two gives Jumarie's overall measure of *subjective entropy* or *subjective information*.

This amounts to a two stage Shannon-like process. At the first stage a particular symbol (e.g., the word ''may'') is generated. At the second stage an observer attaches a meaning to the particular symbol generated (e.g., ''is able to,'' ''is allowed to,'' ''fifth month of the year''). The meanings are related to the symbols by a system of conditional probabilities defined in advance by the subjectivity of the particular observer and dependent on the context. So the particular sentence in which ''may'' occurs, and the prior expectations of the observer determine the conditional probabilities from instant to instant. Thus, there is a measure of the syntactic information of the source of messages, and a measure of the semantic information for each possible message dependent on the observer. The result is the overall measure of subjective information.[10]

This approach does provide an extension to Shannon's formula to cope with the idea that a particular symbol may have a number of meanings, and it does provide a role for individual observers in assigning meaning to symbols. Thus it does provide a definition of information and distinguish it from meaning. However, it would seem to have very limited practical use within information systems. Like Bar-Hillel's scheme, it is completely impossible to operationalise in anything but a limited, artificial domain. And even if it were the result would only be a measure of the amount of information once again, in this case for a particular source/observer/time combination. Nothing is said about the *content* of particular messages. Moreover, the assumptions about how interpretation

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[8] This is a common interpretation (Brillouin, 1962) since the formula for entropy and Shannon's formula for the amount of information are essentially the same. Conceptually, the link is that entropy measures the degree of disorder of a system in terms of the number of possible states and their likelihood. The more disordered a system is, the greater the degree of randomness, and the greater the amount of information generated by knowledge of the state of the system.

[9] That Shannon's theory may apply at the syntactic level is contentious. I would agree with both Nauta (1972) and Stamper (1973) that it applies only below the level of syntax.

[10] Symbolically, if α refers to the domain of symbols, α' refers to the domain of meanings, and H is a measure of entropy (or information), then $H(\alpha\alpha') = H(\alpha) + H(\alpha'|\alpha)$ and $H(\alpha'|\alpha) = \Sigma p(A_i) H(\alpha'|A_i)$, where A_i are all possible symbols.

operates would seem to be very simplistic. The idea that symbols are interpreted one at a time by selecting from some predetermined set of possible meanings does little justice to the rich complexity of social interaction.

4.2.3. *Information as Reduction in the Receiver's Uncertainty*

A number of authors have taken Shannon's basic idea that the amount of information is related to the degree of uncertainty and applied that to the receiver of information. Information is that which reduces uncertainty in the mind of the recipient.

Hintikka (1968, p. 312) defines information as

> The information of [a statement] *s* is the amount of uncertainty we are relieved of when we come to know that *s* is true.

Hintikka then considers various ways of measuring this reduction in uncertainty basing his ideas on Bar-Hillel and Carnap's concept of the number of states that a statement excludes. The amount of information is inversly proportional to the probability (of the truth of) the statement, or how surprising or unexpected the statement is.

This proposal does not move far beyond that of logical information. It still deals only with measurements of the amount of information, not its content, and although it brings in the receiver, the degree of uncertainty is considered to be the same for all. Thus it does not measure uncertainty for a particular individual, given their prior knowledge, only uncertainty for an ''ideal'' receiver.

Nauta (1972) and Artandi (1973) do bring in the actual state of knowledge of a receiver. Nauta (1972, p. 179) describes *pragmatic* information as ''that which removes the doubt, restricts the uncertainty, reduces the ignorance, curtails the variance.'' This clearly makes information strictly relative to the receiver. The more prior knowledge that the receiver has, the less information that a message can provide. Indeed, a message that is repeated must convey zero information since it is already known by the recipient. Conversely, the message must be comprehensible to the receiver for it to reduce uncertainty, so messages in unknown languages or unfamiliar symbolic systems also convey no information for particular people. Nauta (1972, p. 222) also clarifies the pragmatic nature of information by making it clear that the uncertainty to be reduced is always relative to particular purposes or goals.

> As such pragmatic information is directly related to human VALUES; not only ECONOMIC values (resulting in a cash-value . . .), but also ETHICAL and AESTHETIC ones. For reasons of simplicity, however, the discussion is usually restricted to economic contexts; we will have to do the same here. (original emphasis)

This approach is certainly a significant step forward in moving information concepts towards the level of practical use. It begins to consider the actual *content* of messages by recognising that what they convey to someone will

depend upon that person's prior knowledge and expectations, rather than being concerned only with the *amount* of information. It also represents one of the first attempts to consider the pragmatic dimensions of information by making the link between information and purposes and values. However, compared with the evaluation critieria the approach is still quite limited in its usefulness.

(i) In terms of generality, there is a move towards the semantic and pragmatic levels, and although Nauta and Artendi seem to assume a context of conscious linguistic communication, it seems to me to apply equally to natural and unintentional signs and gestures. Seeing rain clouds may well reduce one's uncertainty about going on a picnic or, conversely, increase it (see below).

(ii) The approach is weak, however, in terms of its actual definition of information. Information is "that which reduces uncertainty" but *what* exactly is it? Is it the message or sign itself? This seems unlikely as the same information could be represented in quite different ways. It is the *meaning* of the message? This is a possibility but one of the weaknesses of the theory is that meaning is not discussed. Such an interpretation would equate information with meaning but this is quite problematic. For example, there are sentences that are meaningful but that could not carry information such as "all circles are circular." Fox (1985, p. 94), discussed below, also gives examples where meaning and information are clearly different. Moreover, it is not clear that Nauta's definition is actually consistent with Shannon's. Nauta defines the amount of information as the actual decrease in uncertainty of choice of the receiver, but Shannon's measure concerns the absolute amount of uncertainty associated with a source. Nauta suggests that this can be overcome by assuming that Shannon measures *potential* information, while Nauta measures the actual information received.

(iii) Aside from the detail of definition, is reduction in uncertainty actually a reasonable interpretation of information anyway? It seems to go against common usage of the term. For instance, it implies that books, newspapers, messages, and so on, do not carry information in themselves. Information comes into being only when someone reads them—so a library or information system does not contain any information when it is not being used. It also means that a message that is repeated carries information the first time but not the second. It seems more intuitive to say that the message still carries information but the second time it has no *new* information for the recipient. Moreover, it does not seem clear to me that information always reduces uncertainty—could not information increase it. To take the example above, one may be *certain* of going out for a picnic until one receives information that it may rain. This information may well introduce or increase uncertainty.

(iv) It is also unclear how relevant or useful this conception actually is for information systems. Aside from providing a general orientation towards information as reduction in uncertainty, it is apparent that this type of measurement could not actually be operationalised.

4.2.4. *Information as a Change in Cognitive Structure*

The idea that information is some change in the receiver has also been proposed by MacKay (1956, 1961, 1969; Bednarz, 1988), who explicitly tried to incorporate meaning into information theory. This approach has been further developed by Luhmann (1971, 1990), a notable sociologist. I would argue that it is the approach which is nearest to providing a theoretical underpinning for Checkland's formulation of "information equals data plus meaing."

MacKay's analysis is concerned primarily with intentional communication through language (although he does indicate that it could also apply to nonintentional signs and symbols). That is, a situation with a sender who has a meaning they wish to transmit, a message (statement, question, command) intended to transmit the meaning, and a receiver who is in a particular "state of readiness." This state of readiness can be interpreted as a set of conditional probabilities for different possible patterns of behaviour in different circumstances. MacKay refers to this as a conditional probability matrix (C.P.M.). The intention of the sender is thus not to produce some actual behaviour, but, through an understanding of the message, to alter the settings or state of the C.P.M.

There are three different "meanings" involved in such a communication— the intended meaning of the sender, the received or understood meaning of the receiver, and the conventional meaning of the message.[11] There is clearly an enormous degree of complexity involved here. For example, the conventional meaning might be completely negated by a tone of voice or expression in an ironic or sarcastic comment. That aside, what is the exact nature of "meaning" implied here? Mackay argues that one cannot identify the received meaning with either the behaviour brought about, the change to the C.P.M., or the final state of the C.P.M. Rather meaning is a function or trigger, "*the selective function of the message on an ensemble of possible states of the C.P.M.*" (MacKay, 1956, p. 219). The three types of meaning now become the intended selective function, the actual selective function, and the selective function on a "conventional symbolic representational system."

Some illustrations of this concept are: two messages may be different but have the same selective function (meaning) for a particular receiver; the same message repeated still has the same meaning even though it brings about no change of state the second time; a message may be meaningless if it has no selective function for someone, for example if it is in an unknown language or is an inappropriate choice or combination of words. Note that this concept of meaning is relational—the selective function is always relative to a particular

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[11] This conventional meaning is a problematic concept, but could be interpreted in Habermasian terms as that meaning which any competent speaker of the language should understand (see Mingers, 1995b).

ensemble or domain. So two messages which are different may have the same function in one domain but not in another.

We can now connect meaning with information theory. What MacKay calls *selective information content* is the size or extent of the change brought about by a particular selective operation. This obviously depends on the prior state of the C.P.M. Thus, a repeated message will be meaningful but will have no information content since no change of state will take place, the C.P.M. will already be in the selected state. So meaning is a selection mechanism which may generate information for someone if it changes their state.

A similar, although less clear, definition is offered by Pratt (1977). He uses Boulding's (1956) concept of the individual's *Image* or worldview instead of MacKay's C.P.M. and points out that when someone has understood a message he/she has become *informed*, or rather, ''in-formed.'' That is, their Image is re-formed or altered. Thus ''in-formation'' is the alteration to the Image on the receipt of a message, it is an event occurring at a particular point in time. This, however, leaves a problem with the nature of *meaning* that is never resolved. Pratt quotes Boulding as starting that ''the meaning of a message is the change it causes the Image,'' but surely that is just how information has been defined? Otten (1975) similarly suggests that information is some change of state in a system. He proposes a very general framework of communication within which information transfer can take place based on the traditional model of an organism or system interactively adapting within its environment. Thus information is interpretations or transformations of incoming stimuli which are manifested in internal changes in the state of the system. However, this very general conceptualization does not seem to go beyond MacKay's.

Luhmann (1990) has, however, developed MacKay's work further by tieing it in with his sophisticated, phenomenologically based, theory of meaning-constituting systems.[12] Luhmann aims to move the discussion of meaning away from the perspective of the conscious intentions of individual subjects (as with MacKay) towards recognising that meaning is primary and should be defined without reference to the subject's intentions since the subject is already a meaning-constituted entity. Luhmann takes MacKay's idea that meaning is not primarily content, but a function for *selection*. Meaning functions at two levels—the psychic (individual), where it frames or orders our experiences, and the social (society), where it makes possible intersubjective experience and communication. Meaning, in fact, connects these two levels and makes possible their differentiation.

Considering the individual level, we constantly experience a multiplicity of external and internal stimuli. This, in fact, constitutes a major problem for

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[12] The following discussion of Luhmann draws on helpful exchanges with Dirk Baecker.

us—we are continually overburdened by possibilities and must in some way select or choose which of our immediate motor–sensory perceptions will become actual experiences for us. This is the function of meaning—to allow a selection from the many possibilities without at the same time losing that which is not selected. In selecting from our perceptions and presenting us with experience meaning always opens up further possibilities with its implicit references to the alternatives that have not been chosen.

Meaning is a relation between what is selected (presenced) and what is not. What *is* selected is only as it is by virtue of its difference from what it is not. Meaning connects present actuality to future possibility. It is the way the present is selected, and is the connection to the next instant's selection. It can be characterised by differences, or rather negations (what is *not* selected), in three domains—factuality, *what* is selected, sociality, *who* is selected, and temporality, *when* in terms of before/now/after. The particular selections made depend on our individual preexisting set of readinesses or expectations, but the resulting experiences may, in turn, change our expectations. It is this change that Luhmann terms *information*—the surprisal value of a meaning complex for the structure of expectations. As before, information is always relative to the receiver while meaning is not. Thus the same message or event will produce different information for different people depending on the extent to which it accords with their prior expectations. And a repeated message retains its meaning but loses its information. Much more could be said about Luhmann's complex social theory of communication based on autopoiesis (see Mingers, 1995a, Chap. 8), and the role of meaning within it, but for the purposes of our evaluation it is sufficient to note its existence.

In terms of our criteria, MacKay's interpretation of meaning and information, as developed by Luhmann, is the most promising so far considered. It is broadly similar to, but a definite improvement over, the idea of information as reduction in uncertainty. First, it is quite general covering both events and language, and dealing explicitly with the semantic if not the pragmatic dimension. More importantly, there is a well-developed articulation of the nature of meaning which links in to a particular set of sociological theories. It appears, at least potentially, able to deal with the full richness of human social interaction. The definition of information as a change in expectations is also more general and more useful than that of reduction in uncertainty. Finally, as mentioned above, it seems to fit very well with Checkland's view of information. Data (events, symbols, messages etc.) cause perceptions which are selected and interpreted through meaning, generating, in the receiver, information.

However, this approach does not overcome all the weaknesses of the Nauta/ Artendi theory. In particular, it leaves us with information being entirely subjective and individual, unable to be carried or contained or processed in any

way as normal usage would have it. It is difficult to see what use could be made of such a definition other than to say that we all experience the world differently.

4.2.5. Dretske's Theory of Information Flow and Knowledge

Dretske (1981, 1983) has produced, from a philosophical perspective, a theory of semantic information and its relation to meaning which is exactly the obverse of MacKay and Luhmann's. Instead of meaning generating information, information is seen to generate meaning. Dretske is ultimately concerned to explain how we come to have everyday *knowledge* of the world, e.g., that someone is at the door when the bell rings, and sees information as a causal component of knowledge.

His central tenet is that signals (that is events, signs, symbols, messages etc.) *carry* information. In particular, they carry information about their own causes or origins. The ringing of a door bell carries the information that someone is there pressing it. Following Shannon, Dretske suggests that we could measure the *amount* of information carried by a particular event in terms of the other possible events that could have happened and their probabilities. However, as we have already seen, this is only an average measure and tells us nothing about *what* the particular information is. Dretske moves on to consider how information can be communicated—that is, how one event or signal can carry information about another. This can only happen if there is a causal link between the two. If the state of one affects the state of the other. The pressing of the bell causes the bell to ring, causing me to hear it, causing me to know someone is there. Information *that* there is someone at the door has been transmitted.

We could measure the amount of information transmitted in terms of the possible states of the source and receiver and the conditional probabilities that connect them, but again Dretske is more concerned with what is transmitted. However, we should note that the amount of information must be relative to the knowledge of the observer. The information that the winner of a horse race was a grey carries more information for someone who knows there was only one grey. Dretske then defines information as *the propositional content of a signal*. That is, that which the signal necessarily implies about states of affairs in the world. In other words, what must be the case, given the existence of this signal, and not necessarily otherwise.[13]

Briefly, this definition has the following implications. (i) The information carried by a signal is objective, independent of the observer. It exists even if it is not observed (i.e., the rung bell still carries information even if no one hears it) or if the observer cannot extract it (for example, because it is in an unknown language). (ii) Information must be *true* to be information. The only *information*

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[13] Formally, "a signal r carries the information that s is F iff the conditional probability of s's being F, given r (and k), is 1 (but given k alone is less than 1)" (Dretske, 1983, p. 57), where k represents the prior knowledge of the observer.

that a signal carries is that which is true about its origin. (The ringing door bell only carries the information that someone is there *if there is someone there*. If it is ringing because of a faulty connection, *that* is the information it carries.) That which is believed to be true but is actually false is not information. (iii) Information can be transmitted, stored, and recorded by machines (e.g., computers!) and in books provided that there are functioning causal links between the transmitters and the receivers. (iv) The information carried by a message is different from its meaning since the information, the propositional content, also carries all the consequences that follow from that proposition (Dretske calls this "nested" information). Thus, saying "this is a glass of water" carries the information that it is hydrogen and oxygen, and boils at 100°C (among many other things), but this is not what the sentence *means*. (v) Equally, a sentence could be meaningful but carry no information if its proposition was false, for example, "circles have four sides." (vi) However, the information conveyed by a message does depend on the meaning, or sense, of the message, not just the referent. For instance, "the woman who had the accident is better" and "my sister is better" carry different information even if they refer to the same person.

Machines, such as televisions or computers, transmit all the information they receive, but cognitive systems such as brains can be *selective*—they exhibit intentionality. That is, out of the large amount of available (nested) information, only some is selected and passed on as a belief or message. Dretske calls this the semantic content of the signal and it is equivalent to meaning. Dretske terms this process of selection a *digitalization of the analog*. Signals in the world and our perceptions of them are generally analog—they are rich in information. Our nervous system processes these perceptions to focus on some particular aspect of the scene which becomes our conscious experience of it—its meaning for us. The bowl of fruit (analog) becomes digitalized to "I'll eat that ripe apple." Thus meaning is the semantic content of an information source, which is that which is held digitally. This process of selecting from our overrich perceptions is similar to Luhmann's theory, but the terms are reversed. For Dretske, it is the receipt of information which generates meaning in the individual. Information is objective, the meaning it engenders is subjective. For a more detailed discussion see Mingers (1995b).

Two other writers have analyses which seem highly compatible with, although not as comprehensive as, Dretske's. Fox (1983) has conducted a very thorough linguistic analysis of the nature of *informing* and *misinforming* and, correspondingly, *information* and *misinformation*. The main conclusion concerning information (supporting Dretske) is that, ontologically, information is the propositional content of sentences, and it is therefore distinct from the meaning of sentences. A proposition is a representation of the way the world is. A given sentence may express many different propositions depending on context,

and it is the meaning of the sentence which selects the particular proposition(s) and therefore information that the sentence contains. The information that a sentence *conveys* to someone is that which causes a change in their belief state and is thus dependent on the recipient (i.e., what Dretske would term meaning). The main difference from Dretske is that Fox claims that information does not need to be true (although misinformation must be false). Thus, to say someone gave information about an accident is an acceptable usage even if the information turns out to be false. I would argue that Fox's analysis may apply to how we use the term ordinarily, but that Dretske's position produces, overall, a stronger theory while still conforming broadly with common usage.

Kary (1990) has developed some tentative ideas of Bunge's. Given two entities A and B, we can talk of information only if A (or some characteristic of it) causally affects B. If this is the case, then B can be used as a source of information about A. For example, a thermometer provides information about the surrounding temperature. So far, this is similar to Dretske but Kary is concerned mainly with the difficulties of extracting the information. He envisages that one will know or approximate the causal link between A and B and then apply the inverse to reconstitute A. However, because of the approximation, and possible changes to B, one can generally only ever obtain an estimate of A. Thus information is defined as the effect of A on B provided there is some means of extracting it, and information processing is the application of techniques to B in order to best reproduce A. The brain is said to extract information about the outside world (A) using changes of state in its sensory surfaces (B).

In evaluating Dretske's theory it appears to satisfy most of the criteria. It provides a clear definition of information and meaning, and proposes a mechanism whereby information generates meaning. It is very general covering all types of signs and signals, not just conscious language. It would seem to be compatible both with the realities of information systems practice and with other disciplines such as social theory and organizational behaviour. Finally, in contrast with Luhmann's version, it accords generally with the commonsense usage of the term information allowing books to contain information and computers to process it.

4.2.6. Summary

There is a wide range of approaches to the nature of (semantic) information all based in some way on Shannon's information theory—the idea that information in some way concerns a reduction in the number of possibilities. The main point of debate has been about how meaning and the observer are brought into the process. The two most successful theories have been found to be those of MacKay/Luhmann and Dretske. Both give clear, although differing, accounts of information and its relationship to meaning and generally meet the evaluation criteria. Dretske's is to be preferred because of its greater compatibility with

other disciplines and common usage of terms. We shall now briefly consider some information theories not based on Shannon's work.

4.3. Non-Shannon-Type Information Theories

4.3.1. Information as a Representation of Knowledge

Farradane (1976) has proposed, from the point of view of information science, that the term information should denote representations or surrogates for individual knowledge or thought. He sees information as being part of a communication process. One individual has particular thoughts or knowledge to be communicated; these must be converted into some form of external medium, typically language but possibly gestures or pictures; finally, these representations or knowledge surrogates are converted back into thoughts or concepts (not necessarily the same) by the receiver. Farradane (1976, pp. 99–100) thus defines *"information' as any form of these representations or surrogates of knowledge, or of a particular thought. . . . Information, thus defined, does not include the effect on the recipient, or user, and thus excludes the question of novelty or usefulness or even meaning to the user. . . . "*

In terms of our evaluation this approach to information is not helpful. It identifies information with the *form* of representation rather than with the *content* of the representation (i.e., some state of affairs in the world) or with the *effect* of the representation on someone or something. This seems to make information purely a matter of syntax and not at all of semantics. This is confirmed by the explicit rejection of meaning—i.e., the relationship of the representation to the thought of either the sender or the receiver.

4.3.2. Information as Structure or Structuring

Implicit in many of the conceptions of information that we have discussed is the idea of *organization*—the organization of an information source, or the organization of cognitive expectations. Thompson (1968) explicitly considers the relationship between information and organization. He argues that raw experience or raw data means nothing until it has had some order or organization imposed on it. We might therefore argue that information is the product that results from organizing raw experience. However, Thompson points out first, that we cannot work only with what we have actually experienced—we always go beyond the data—and moreover, that our theories are always underdetermined by experience. *"Data are to the scientist like the colours on the palette of the painter. It is by the artistry of his theories that we are informed. It is the organization that is the information"* (Thompson, 1968, p. 306). In other words, it is the actual structuring of the data/experience, whether conceptual or indeed physical, as in a book, that is informative. New data becomes informative,

becomes information, only to the extent that it is incorporated in an altered organization.

This rather general characterization has been developed by Belkin and Robertson (1976) within the context of information science. They suggest that, in general, "*information is that which is capable of transforming structure*" (p. 198), and in information science in particular, it is "*the structure of any text which is capable of changing the image-structure of some recipient*" (p. 201). A text is defined as "*a collection of signs purposefully structured by a sender with the intention of changing the image-structure of a recipient*" (p. 201). In other words, we have a situation in which a sender, with a particular image-structure, deliberately creates a text (e.g., information systems report or screen) with a particular structure, in order to change the receiver's image-structure.

The problem with this approach is that it is both too specific, and too general. It is too specific in being restricted to conscious, purposeful communications via texts and thus ignoring the information available through non-conscious and natural signs and signals. It is too general in not really providing a distinctive characterization of information. A text consists of a collection of signs with a particular structure; but by identifying information with the structure itself, surely the term information as such becomes redundant. If information is not, in some sense, more than or different to structure then it has no role to play and we may as well just refer to structure.

5. CONCLUSIONS

The purpose of this paper has been to evaluate a comprehensive range of information theories and concepts in order to judge which, if any, might serve as a basis for a practical definition of "information" within the discipline of information systems. It has covered 16 distinctive proposals, the majority of which are informed, to a greater of lesser extent, by Shannon's seminal work.[14] The criteria used in the evaluation were the generality of the theory, particularly its applicability at semantic and pragmatic levels; its appropriateness as a basis for the discipline of information systems; its consistency with other disciplines; and its consistency with common usage.

Many of the theories were found to be very limited or impractical but two did have considerable potential—the MacKay/Luhmann sociological model in

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[14] For the sake of completeness and other researchers, I should mention several theories that I could not cover. Stonier (1990) has argued, based on the relationship with entropy, that information should be seen a fundamental part of the physical universe along with matter and energy. Devlin (1991) has proposed a mathematical approach based on situation theory in which a mathematical object called an "infon" is posited. This is a discrete unit of information which always refers to a particular situation.

which meaning generates information, and Dretske's philosophical theory in which information generates meaning. Of the two Dretske's was preferred as it gave a clearer definition of both information and meaning, and accorded better with common usage of the various terms involved. Further development is now being carried out (Mingers, 1995b, 1996) to provide a richer conceptual framework by incorporating concepts from autopoiesis and critical theory.

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