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What is Information such that there can be Information Systems?

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Abstract

Information systems, as a discipline, is concerned with the generation, storage and transmission of information, generally by technological means. As such, it would seem to be fundamental that it has a clear and agreed conceptualization of its core subject matter – namely "information". Yet, we would claim, this is clearly not the case. As McKinney and Yoos point out, in a recent survey of the term information within information systems: "This is the IS predicament – using information as a ubiquitous label whose meaning is almost never specified. Virtually all the extant IS literature fails to explicitly specify meaning for the very label that identifies it." We live in an information age and the vast majority of information (whatever it may be) is made available through a wide range of computer systems and one would expect therefore that information systems would in fact be one of the leading disciplines of the times rather than one that appears to hide itself in the shadows. Governments nowadays routinely utilize many academic experts to advise them in a whole range of areas but how many IS professors ever get asked? So, the primary purpose of this paper is to stimulate a debate within IS to discuss, and try to establish, a secure foundation for the discipline in terms of its fundamental concept – information. The structure of the paper is that we will firstly review the theories of information used (generally implicitly) within IS. Then we will widen the picture to consider the range of theories available more broadly within other disciplines. We will then suggest a particular approach that we consider most fruitful and discuss some of the major contentious issues. We will illustrate the theories with examples from IS.

Introduction

Information systems, as a discipline, is concerned with the generation, storage and transmission of information, generally by technological means. As such, it would seem to be fundamental that it has a clear and agreed conceptualization of its core subject matter – namely "information". Yet, we would claim, this is clearly not the case. As McKinney and Yoos (2010) point out, in a recent survey of the term information within information systems:

"This is the IS predicament – using information as a ubiquitous label whose meaning is almost never specified. Virtually all the extant IS literature fails to explicitly specify meaning for the very label that identifies it." (p. 329)

This would perhaps not matter if there was general agreement within the discipline about a definition of the term, but there is not. Again, as McKinney and Yoos' survey shows:

"IS research has yet to produce any theory on what information means, its scope or the implications of its various definitions. IS has nominated a plethora of attributes … But there has been little debate or dialogue to build a theoretical foundation for information." (p. 329)

This "scandal of IS" is even more bizarre when we consider two other factors. First, in disciplines outside IS, from cognate ones such as library and information science (LIS) and computer science to far removed ones such as philosophy, biology and even physics, there is considerable discussion, debate and development about the nature of information. See for example: Ibekwe-SanJuan and Dousa (2014) *Theories of Information, Communication and Knowledge;* a special issue of *Triple C* (11, 1, 2013); special issues of *Synthese* (175, 2010 and 167, 2009) (a philosophy journal); and a special issue of *Information Research* (15, 4, 2010). There is now a newly created field called the philosophy of information (Floridi 2002b). Major concepts such as the "infosphere" and "information ethics" are being developed (Ess 2014). A significant person in the area is the philosopher Luciano Floridi (2002b; 2004a; 2009a; 2009b; 2011), but his work is hardly ever referenced in IS papers.

Second, as has been said many times, we live in an information age and the vast majority of information (whatever it may be) is made available through a wide range of computer systems and one would expect therefore that information systems would in fact be one of the leading disciplines of the times rather than one that appears to hide itself in the shadows. Governments nowadays routinely utilize many academic experts to advise them in a whole range of areas but how many IS professors ever get asked?[1]

So, the primary purpose of this paper is to stimulate a debate within IS to discuss, and try to establish, a secure foundation for the discipline in terms of its fundamental concept – information. The structure of the paper is that we will firstly review the theories of information used (generally implicitly) within IS. Then we will widen the picture to consider the range of theories available more broadly within other disciplines. We will then suggest a particular approach that we consider most fruitful and discuss some of the major contentious issues. We will illustrate the theories with examples from IS.

In order to evaluate different theories, it is necessary to have some criteria against which to benchmark them. These will of necessity be quite general and qualitative because of the very broad nature of information. We have identified three criteria:

1. **Definitional** clarity. The concept must be well-defined. That is, it must provide a clear and unambiguous description of information, and its ontological and epistemological status (e.g., is it objective or subjective?). It must clearly distinguish it from related concepts such as data, knowledge and meaning.
2. **Practicality.** It must be practically appropriate for use across all spheres of information systems. Behaviorally, it must cover both the theoretical developments of IS as well as the ways that that they are used in practice. This means that it must include both the semantic and pragmatic levels of IS use. And must recognize that information systems always form part of the social and communicational systems of society, and must allow for the negotiated nature of meaning in the social world. Methodologically, it should contribute to the development of IS, and IS research.

[1] This became clear in an interesting Track about practical engagement at ICIS 2013 in Milan

3. **Comprehensiveness.** The concept should be a broad as possible, both in terms of the range of signs and symbols that it covers (signs, gestures, icons, speech, writing), and the range of disciplines that is covers given that information is such a transdisciplinary concept.

Theories of Information within Information Systems

Information as processed data

McKinney and Yoos' (2010) survey found that very few research papers specify the conception of information that they are using. But it is necessary that textbooks do so and this provides us insight into what is the most common, taken-for-granted view. This is the idea that information is data that has been processed or organized in some way to make it useful for some purpose. Stair and Reynolds "*Principles of Information Systems*" (Stair and Reynolds 2014, 11th ed.) has been selected at random as a typical example. They distinguish between data and information as follows:

"Data consists of raw facts, such as employee number, total hours worked in a week, inventory part numbers, or sales orders. … When facts are arranged in a meaningful manner they become information. Information is a collection of facts organized and processed so that they have additional value beyond the individual facts." (p.5)

This idea is what McKinney and Yoos call this the *token* view of information (their other categories being *syntax*, *representation* and *adaptation* which we will discuss later) by which they mean:

"Information in the token view is synonymous with data: both refer to tokens manipulated by processes" (p. 331).

They found that this was the implicit view of information held in 80% of the 60 IS papers they surveyed.

Many authors go on to relate information to knowledge, the so-called data, information, knowledge hierarchy. For Stair and Reynolds, ***"Knowledge** is the awareness and understanding of a set of information and the ways that information can be made useful to support a specific task or reach a decision."* (p. 6). This formulation sees knowledge as being *about* information and its uses. Many other authors would claim that knowledge *comes from* information – i.e., receiving information leads us to have knowledge.

At first blush, this definition of information seems quite clear but as we analyze it more we find that it is in fact very vague and does not account for important questions about the nature of information.

First, as McKinney and Yoos argue, this does not actually distinguish between data and information at all. Information is simply a set of data that has been processed and is thought to be useful. They suggest that on this view we should not talk of information systems, but only data systems. Suppose we have a set of data about managers' salaries – individual facts as Stair and Reynolds would say. If we calculate a mean salary then this would presumably become information as it has been made useful. But what if the data initially was mean salaries perhaps by occupation. Would we then have to calculate a mean of these means to have information? Surely the dataset is quite informative as it is? Looking in the opposite direction, data itself is often already the result of many, quite complex

processes. If our data were company accounts for example, a huge amount of work would have been done to produce them. Surely they should count as information (having been processed and made useful) and not data? So, on the standard view the distinction between data and information is fairly meaningless.

Second, this view presumes that information is objective, that is, the same for all people who might receive it. However, many people would argue that in fact information is at least in part subjective, dependent on the prior knowledge and intentions of the recipient. On this subjective view (called the adaptation view by McKinney and Yoos) data, or more generally signs and symbols, are *interpreted* by an observer and generate information for that person which may be different to the information generated for someone else. As Checkland summarized it, "*Information equals data plus meaning*" (Checkland and Scholes 1990. P. 303). For example, a clock may record the time as 10.15. For one person that means that they are late for a meeting; for another it may mean that it's time for coffee; for a third that time is passing slowly. For Checkland, 10.15 is data and the three different interpretations are three different sets of information derived from the same data.

Third, the processed data view makes no mention of, or perhaps just assumes, that information must be *true* for it to be information. In fact, this is a debatable point. Some people do hold that information must be true for it to be information, otherwise it is simply misinformation, or even disinformation (Dretske 1981; Floridi 2005; Mingers 2013) but others argue that this would be too restrictive a definition (Fetzer 2004). This is related to another weakness which is a failure to distinguish between information and *meaning*. Suppose we receive the information (or perhaps data) that "100 fridges were sold last week". This message clearly has a meaning that any competent speaker of English would understand. But is this identical to the information or is there some distinction, and if so what? One argument would be that it is only information if the sentence were actually true, even though it is meaningful if it is false. This all leads us to consider the relationship between the data/information carried by signs or messages and the states of affairs that they supposedly represent.

There are many other limitations of this rather naïve approach to information which will become clearer as we develop the more sophisticated theories in other disciplines. In terms of the three evaluation criteria, this concept of information fails on all three – it is not well-defined; it is not practically useful; and it is not comprehensive

Theories of Information across other Disciplines

There are, and have been, many information theories and it would not be possible to cover even a majority of them in this paper. We have concentrated on those we feel are best known or have most potential for information systems. For recent overviews of information theories see Bates (2010), Capurro and Hjørland (2003), Zins (2007) and Case (2012). There are certain theoretical constructions that are commonly referenced within the information theory literature and so as not to over-burden the text explaining them, we have put brief descriptions in Appendix 1.

It is clear that the term "information" can be used or applied across the whole spectrum of disciplines from physics to history (Robinson and Bawden 2014). Indeed, it may be more pervasive or general than concepts such as matter and energy which are limited to physical systems. It is,

therefore an open question as to whether or not a single, very broad, definition of information could ever fit all these fields, or whether there needs in fact to be several, or many, definitions dependent on context. We shall not cover this debate specifically although we do support those who are trying to develop a genuinely transdisciplinary conceptualization of information, such as Brier (2008), Floridi (2011), Beynon-Davies (2010) and Hofkirchner (2013). For our purposes, what is important is that we produce a theory that is broad enough to cover information systems and its cognate disciplines such as LIS, computer science, AI, cybernetics, and business and management.

We will begin with a brief overview of the main information theories as shown in Table 1. These are organized in terms of the semiotic framework developed by Morris (1938) and Stamper (1991) (see Appendix 1). For a different but interesting typology see Furner (2010). McKinney and Yoos' (2010) taxonomy partially fits this framework. Their syntax view corresponds with ours. Their representation view corresponds with our semantic level. Their adaptation view covers theories that we have at both semantic and social levels such as Checkland, Luhmann and Hofkirchner.

The different interpretations of the concept of information have far reaching implications for the discipline of information systems, both from a research and practitioner perspective. The analysis of the literature shows that information is difficult to define and when we add 'systems' to the mix it becomes even more complicated. Indeed, there are probably as many interpretations of 'system' as there are of information. Notwithstanding this unavoidable added complexity, our focus in this section of the paper is consistent with the aim to discuss ways in which different interpretations of the information concept impact on research and practice. It is clear that organizational context plays an important role in the following illustrations of how definitions of information impact on the value we attribute to information systems. Context relates to organizational culture, policies, procedures, norms and values. These features help shape our understanding of information in a given organizational context

Semiotic Dimension	Information Theories		
Empirical or physical (concerned with physical embodiment and transmission)	Information physics Quantum information	Environmental information	*Bateson*: the difference that makes a difference
Syntactic (concerned with the rules governing symbols)	*Shannon and Weaver*: information as the uncertainty associated with messages; entropy	*Weiner*: information as a measure of the degree of organization; negentropy	
Semantic (concerned with the meaning of information)	*Checkland*: information = data + meaning *MacKay*: change in receiver's cognitive structure	*Dretske*: information as propositional content of signals	*Floridi*: Information as well-formed, meaningful, true data
Pragmatic (concerned with the intention and effects of information)	*Mingers*: similar to Dretske but including personal and social dimensions		
Social (concerned with the social context of information)	*Luhmann*: the surprisal value of a communication for the receiver's cognitive expectations	*Hofkirchner*; The effect that differences in the environment have on a self-organizing system.	*McKinney* and *Yoos*: similar to Hofkirchner – information as the difference made to an observer

Table 1 Theories of information organized by the semiotic framework. Note that some theories apply across more than one level

Syntactic dimension: The mathematical theory of information

It is convenient to start with Shannon and Weaver's mathematical theory of information (MTI) (Appendix 1) at the syntactical level as that relates both down to physics and up to semantics. MTI is syntactical because it is based on the number of possible messages or codes within a system, but says nothing about the actual meaning or content of the messages. It is like measuring the size of a container but knowing nothing of what is inside. The fundamental conception, picked up in many other theories, is that information relates to uncertainty or surprise. The greater the degree of uncertainty, the more surprising is the actual result and thus the more information that is received. Or, put the other way, information is that which would be needed to reduce the receiver's uncertainty to zero. This also implies that if one already knows the answer, a further message will contain zero information since uncertainty is already zero. This has the counter-intuitive consequence that the greater degree of disorder in a system (entropy) the greater the amount of information that it has. As noted in the Appendix, Weiner's definition is identical to Shannon's but with a reversed sign so that information is associated with negentropy, organization and order, rather than disorder. So the interpretation here would be that information is that which is needed to generate structure and organization.

An area of information systems that takes a syntactic approach to information is telecommunications since its focus is to measure the transfer of information by technology, the structure of information (packets) and reliability of transmission to maximize throughput. Another

analogy is the management of IT resources and networks in an organization where the primary objective is to deliver adequate service related to speed of communication, storage capacity and reliability of service without specific regard to the meaning of what is being managed (Weill and Broadbent 1998). The more recent trend of cloud computing can be seen as an extension of this perspective in relation to delivering improved service and reliability in a cost effective manner often without regard to the meaning of the information being managed. Key opportunities and obstacles of cloud computing are seen mainly as throughput performance related: availability of service, data transfer bottlenecks, performance predictability, scalable storage, and software licensing (Armbrust et al. 2010).

In a critical review of cloud computing, Venters and Whitley (2012) identify two cloud perspectives, a technical perspective and a service perspective that are defined in terms of desires of users and potential users. The technical desires include security equivalence, availability of service, and performance at least equivalent to current services (non-cloud services), capability to manage complexity but where the complexity is hidden, and a service that scales up to keep pace with demand. The service dimension of cloud computing includes economic efficiency, simplicity in concept and use, and capability to facilitate creativity. Both the technical and service dimensions largely focus on cloud computing as a utility with little or no regard to the nature of information being managed. Some understanding of the information being managed may be necessary to improve organizational creativity that can result from the capability to more quickly adopt new technologies as they become available via the cloud and the likelihood of greater trialing of niche services. However, it is recognized that the capability of organizations to become more innovative relies on more than technological infrastructure (Ciborra 1996) indicating that this 'desire' may be difficult to realize in cloud platforms as in other platforms.

The implications of taking a syntactic approach to information management are significant. The scope of responsibility of IT project managers is impacted since a syntactic view would be concerned about the efficiency, flexibility and accessibility of information rather than its meaning. In some organizational contexts this technical view may be satisfactory or even desirable but in other organizations expectations may involve understanding the information content to help drive business value through, for example, innovation and creativity. Clarifying the boundary of responsibility related to information understanding can determine the perceived strategic value of information systems and so makes it significant to both practitioners and researchers.

A utility view of information infrastructure can infer that IT practitioners and researchers do not have concerns about the meaning of the information flowing through systems but this is not usually the case. Issues related to confidentiality in cloud computing and ethical use of systems are widely seen as IT responsibilities and these require some understanding of the meanings attributed to the information being managed. For example, time spent on personal social media use whilst at work is an issue for some organizations (Rosebush 2012). Hence, an analysis of the content and meaning of the information can enable those responsible for managing a system to make more informed decisions on improving IT infrastructure service or denying access to certain applications or web sites.

In terms of our evaluation criteria, the MTI is well defined, at least as far as measuring the quantity of information, and is fairly broad, but it does not deal with semantic, pragmatic or social aspects of information or really specify the "content" of information at all.

Physical dimension

We can now move down the hierarchy to briefly mention physical and quantum information. The idea that information might be a fundamental property of the physical world, along with matter and energy, arose with the relationship to entropy mentioned above through the work of scientists such as Boltzmann and Szilard (Zurek 1989). Brillouin (1929) recognized a formal mathematical link (based on Weiner's formalism), and Landauer (1991) proposed that "information is physical", i.e, must always be embodied in some physical form, and that physical laws can be cast in informational terms. The physicist John Wheeler went further to suggest that everything physical actually derives from informational questions - "it from bit":

"every 'it'— every particle, every field of force, even the space-time continuum itself— derives its function, its meaning, its very existence entirely— even if in some contexts indirectly— from the apparatus-elicited answers to yes-or-no questions, binary choices, bits." (1990, p. 310)

Two other approaches worth mentioning are quantum information and the holographic principle. Quantum information theory (Nielsen and Chuang 2000) is analogous to Shannon's information theory but at the level of the quantum state. This is the most fundamental distinction we make at the moment where a particular quantum object, such as a photon, can be in one state or another, or in fact the two states may be superimposed. The basic unit has been called a qubit and is the foundation for quantum computing which promises to be the next revolution in computer science. The holographic principle (Bousso 2002) arises from the entropy/information relation and is the idea that all the physical information in a 3D world is actually held in 2D on the boundary surface rather like a hologram portrays a 3D image despite being only 2D (Bekenstein 2003).

These theories generally follow the Shannon information approach which means that they are objective, i.e., observer-independent, and also non-semantic, i.e., do not include meaning

We have also put Bateson's (1973a) idea of the "difference that makes a difference" (Appendix 1) here at the physical level since that is where it starts out although it is in many ways a transdisciplinary concept. Although this concept remains at a very general and undefined level in Bateson's work, it has been fruitful in informing many other information theories including Floridi, Brier, Hofkirchner and Mingers. This is because it provides a link between the physical world, wherein information must be embodied or represented, and the cognitive world of the mind. A difference is fundamentally a relationship not a thing. The differences between an egg and an apple are not located in the egg or the apple or even in the space between them, but rather in the relations between the two. As Maturana and Varela (1980a) have demonstrated, the fundamental operation of the nervous system is to detect or react to relations in the environment. Thus external differences can trigger differences in the nervous system and hence "make a difference", i.e., generate the basic conceptual or perceptual "idea". This is distinct from Shannon's theory as it does begin to take us into the world of meaning and semantics.

Following from Bateson is the idea of environmental information rather than conscious human communicative information. The question here is, do we accept that events in the environment

leave traces or signs that carry information? For example, paw prints in the ground, black clouds in the sky, or animals marking their territory. If we do, then it implies that organisms other than humans can receive and process information. Some information theorists do, but others restrict information to intentional human activity. C. S. Peirce (one of the founders of semiotics) was clearly in favor:

"The action of a sign generally takes place between two parties, the utterer and the interpreter. They need not be persons; for a chameleon and many kinds of insects and even plants make their livings by uttering signs, and lying signs at that." (Peirce 1907, 318, S. 17)

Semantic dimension

In considering semantic information we are moving to include the content or meaning of signals and messages, not just their quantity. Some of the main debates are: is information different from or the same as meaning? Is information objective, subjective, or perhaps both? Does information have to be true or correct to be information? How does information relate to knowledge?

We saw in the introduction that the most common view in IS is that information is objective and (implicitly) true, being processed data. One of the first to argue against this was Checkland, the founder of soft systems methodology (SSM), who proposed that "*information equals data plus meaning*" (Checkland and Scholes 1990. P. 303).

"The most important feature of this analysis of data, capta, information and knowledge is that the act of creating information is a human act, not one which a machine can accomplish. It is the human being who can attribute meaning to the selected data … in a context which may well be shared by many people but may also be unique to an individual." (Checkland and Holwell 1998, p. 91)

What this means is that data provides basic facts about the world but these facts are interpreted differently by different people according to their intentions, beliefs, values and expectations (meaning), and information is what results *for the individual receiver.* Thus, if a system records that there are 15 widgets available (data) one person may conclude that that is sufficient for what they need , another that more should be ordered, and a third that the system is wrong as there are only 12 (information). This is in many ways an appealing view as it seems clear that we do indeed interpret the world differently, but it is rather vague – what exactly are data, meaning and information, and how does meaning interact with data to produce information?

Checkland's view, applied to business intelligence systems' use, would imply that the system only produced data to inform the user and that the users' interpretation of the data produced information to act upon. It also implies that different users would do this in their own unique way given their own experiences, knowledge and skills and this would result in many different courses of action. Literature on intelligence gathering for decision-making has shown that managers are driven by a variety of motivations and take different approaches in gathering intelligence (information) for decision-making. Social motivation researchers, for example, contend that decision-makers' beliefs and motivations lead them to look for information that attends to those motivations and beliefs, often to subjectively support their position (Nutt 2007). Whilst subjectivity in decision-making is common, research on the topic does not show that managers believe their IT systems do not produce information, rather that they focus on certain aspects of the information, or even ignore it altogether.

MacKay (1956; 1969) also proposed that information was subjective, in particular that it was the change in a person's cognitive structure brought about by a message. This approach was further developed by the sociologist Luhmann, who will be discussed later, and provides the best theoretical underpinning for Checkland's theory. MacKay was primarily concerned with intentional linguistic communication (although not ruling out more basic signs and gestures) consisting of a sender with a meaning they wish to transmit to a receiver via a message. The receiver is assumed to be in a particular cognitive "state of readiness" conceived of as a conditional probability matrix (CPM) of various possible behaviors. The intention of the sender is not to actually produce a specific behavior, but to change the settings of the CPM once the message has been understood. In this model, there are three different kinds of "meaning" – the intended meaning of the sender, the meaning the receiver understands, and the conventional meaning of the message[2]. Meaning is interpreted operationally as "*the selective function of the message on an ensemble of possible states of the CPM*" (Mackay 1956, p. 219). So, meaning is a dynamic concept, one that brings about or selects a change in a CPM. Finally, information is not the same as meaning, but is the size or extent of the change brought about to the receiver's CPM by a particular meaning.

Some implications of this view of meaning are: Two messages may be different but have the same meaning, i.e., selective function, for a particular receiver. A message may have different meanings for different people, and thus generate different information. A repeated message still has the same meaning but does not create information as the state has already changed. A message can be meaningless for the receiver if it has no selective function perhaps because it is in a foreign language, although still have meaning for the sender. Overall, this theory does provide a clear distinction between information and meaning, and does recognize some of the complexity of the idea of "meaning", but it makes "information" purely subjective, dependent on the prior state of the receiver, and leaves the nature of the information rather vague – how can we capture the change to someone's CPM? It is thus not that useful, methodologically, for IS. It also means, as does Checkland' theory, that computer systems cannot be said to contain or process information, only data and, equally, that books, newspapers timetables etc. do not contain information.

McKay's cognitive model emphasis is aligned with the user-subjective approach to personal information management systems (Bergman et al. 2003). In this, use is made of subjective, or user dependent attributes related to individuals' cognitive schemas. It argues that interface displays of information should take into account how the user understands the information in terms of importance, relationships with other information and context of use. This design approach should help the user find the information item, recall it, and use it effectively. In designing systems based around an individuals' perceptions and use of information that are often episodic and idiosyncratic, it could be argued that the resulting interface is only fully understandable to the individual. In other words, its value is subjective and of little use to another user.

Moving to the philosopher Dretske (1981; 1995), he has produce a theory of semantic information that is almost the opposite of MacKay's. Instead of meaning producing information, information is seen to produce meaning, and ultimately knowledge for the individual. Dretske's fundamental idea is that all sorts of signals, primarily physical one, *carry* information. In particular, they carry

[2] The conventional meaning of a message is a tricky concept, but can be equated with Peirce's immediate interpretant (see Appendix 1), and Habermas's concept of a competent speaker of a language (Habermas 1970)

information concerning their own causal origins. Given that a particular sign or event has occurred, what must be the case because of that, but not necessarily otherwise? What must have happened to have generated it?[3] This is what he calls the propositional content of the signal and is what he identifies as semantic information[4]. Thus, a knock on the door carries the information that there is someone there. A fuel gauge in the car carries the information that the tank is half full. A database carries the information that there are 15 widgets in stock[5]. A photo carries much information about the scene it portrays.

Dretske next considers how information can be transmitted from a source to a receiver (which may be machines rather than people). For this, there must be a causal link or chain of links between the two such that the state of one affects or generates the state of the other. The knocking on the door causes sound waves, which cause me to hear it (assuming I am not deaf), which causes me to know that someone is there. Thus information is transmitted and generates knowledge that something is the case. Information, on this view, is objective, in that it is carried and transmitted whether or not it is received or understood by anyone. However, if it is received, the *amount* of information available to the receiver does depend on their prior state of knowledge. Suppose that we are expecting someone particular to arrive and have arranged for them to give a special knock. When we hear that knock we can derive the information that it is that particular person. Someone who did not know the special knock would only derive the information that a person was there.

Another aspect of Dretske's theory is that information can be held in analogue or digital form. A photo of a room, for example, has a large amount of information in analogue form. When someone looks at the picture, they cannot process all this information (as an electronic mechanism could) but rather they focus on particular aspects of it, depending on their prior interests and expectations, and generate a much more specific concept or description (e.g., "that's nice wallpaper") that only contains some of the information. This intentional process Dretske calls digitalizing the analogue.

This sophisticated theory has several important implications for the nature of information:

1. Information is objective and independent of the receiver. It exists whether or not it is received, and whether or not it is understood.
2. The information that is carried by a signal must be true, i.e., it only carries the information about what is actually the case. So, if the knocking on the door was actually caused by a branch blowing in the wind that is the information it carries even though we might mistakenly think someone was at the door.
3. Meaning is necessary for information but not identical to it. A meaningful sentence may not carry any information if it is not true. The same information may be carried by different sentences, or in different forms (e.g., train times in a timetable, on a website, over a loudspeaker). Messages that reference the same thing can carry different information (e.g., "there was an accident on my way to work" and " the accident on Baker Street")

[3] This is similar to the ideas of retroduction in critical realism (Bhaskar 1978), or abduction in Peirce (1931-1958)

[44] Formally, "A signal *r* carries the information that *s* is *F* iff the conditional probability of *s*'s being *F*, given r (and *k*, the prior knowledge of the observer) is 1 (but given k alone is less than 1)" (Dretske 1981, p. 57)

[5] Assuming that it is correct or true. This will be discussed later

4. The information carried by a message also carries with it the nomic consequences of that information – what is causally implied by it – and this may be more than the meaning. (e.g., calling something a glass of water also carries the information that it is H_2O with all its chemical and physical properties although this is not stated in the meaning).
5. The actual information available depends on the prior knowledge of the receiver. First, the receiver must have the knowledge to understand the signals (e.g., know the conventions or language) to gain any information. Second, there may be different levels of expertise (e.g., if there are flashing lights on a machine that does not work, an engineer will be able glean more information about the problem). Third, specific knowledge of the context may be used (e.g., if you are told that the winner of a horse race is a grey, and you know that there is only one grey, you can identify the horse).

Dretske also considers the relation between information and knowledge[6]. Put very briefly, for this is a contentious subject (Floridi 2010; Mingers 2008), philosophy traditionally defines knowledge as justified, true belief (JTB). In which case, if someone receives information that p is the case, they come to believe it; they have justification for believing it (the information); and it must be true since information must be true. Information thus generates knowledge.

Dretske's semantic view of information can be applied to a variety of IS studies including examining the quality of information produced by information systems. Setia, Venkatesh and Joglekar's (2013) analysis of how information quality leads to improved customer service performance can be used as an illustrative case study. Their study examines how information quality in customer side digital systems influences customer service capabilities in relation to customer orientation capability and customer response capability and how these impact on overall customer service performance. Information quality is measured in terms of completeness, accuracy, format and currency of information produced by the customer service units' digital technologies. Completeness refers to the degree to which the system provides all the necessary information and so includes relevancy of information; accuracy refers to the perception of the information being correct, or true; format refers to the presentation of information; and currency refers to the perception of the information being up to date. The findings of the study indicate that information quality in a customer service unit is a significant determinant of its customer service capabilities. The more sophisticated the customer service processes are the stronger the relationship between information quality and customer service capabilities. The study's findings assume that information is objective since quality has a direct impact on strategic and operational performance outcomes. The notion of information quality implies a relative scale in relation to completeness, accuracy, format and currency; more complete, up-to-date information that has a higher degree of accuracy and is well presented for ease of use will have a greater impact.

In terms of our criteria, Dretske's theory does well in clearly defining information, and distinguishing it from meaning and knowledge. It is quite general in covering a range of signal types and is applicable in other disciplines. It also fits in with traditional IS usage in that information is objective, and can be stored and transmitted by computers. Its limitations are that it does not move up to the pragmatic and social aspects of full human communications, it limits itself to *de re* phenomena

[6] Indeed, that was really his main purpose – his book is called "*Information and the Flow of Knowledge*".

Floridi, a philosopher, has been extremely active and has almost single-handedly created the whole field of information philosophy (Floridi 2002b) and information ethics (Floridi 2002a). He too has a theory of semantic information which is based on both Shannon and Dretske. The theory itself has evolved but we will concentrate on the latest version (Floridi 2011). Floridi recognizes that information may be considered at different levels – technical (syntactic), semantic and influential (pragmatic) but concentrates mainly on the semantic, and also says that the main account in applied disciplines such as IS is the "bipartite" one that relates data to meaning, quoting Checkland (Floridi 2005).

Initially, he characterized semantic information as:

σ is an instance of information, *understood as semantic content*, iff:
σ consists of data;
the data are well-formed syntactically (wfd);
the wfd are meaningful.

He then added a fourth condition, to create what he called a general definition of information (GDI), that the meaningful, well-formed data must be *true* (Floridi 2009b). So, at this point, information is identical to data that is well-formed, meaningful and true, thus apparently making it objective although he is not wholly clear as to whether it is meaningful in itself or meaningful for somebody, which is the essential question. This leads to the further question, which has not been considered much so far, as to what exactly is data?

Here he draws on Bateson, saying that data must ultimately rest on some difference or lack of uniformity in the world which may be between physical states (*de re*), between perceptions (*de signo*) or between symbols (*de dicto*). Data can be decoupled from its physical manifestation (e.g., "2" can be represented in different ways, and semantic information can be decoupled from data (e.g., it could be represented in a graph or writing). This accounts for the huge freedom and complexity in representation and communication. He further suggests several other degrees of under-determination of data:

- Typological neutrality: there may be different types of data, but there is no information without data, although he does allow that an absence can count as information, e.g., a bill unpaid. This is consistent with critical realism's view of absences as causes (Bhaskar 1994).
- Ontological neutrality: Data must be represented in some way and this is usually physical, but he allows for the possibility of a purely information-theoretic representation as distinct from matter and energy (cf information physics). Ultimately though, it must be manifest physically in some way for humans to interact with it.
- Genetic neutrality: data can be meaningful (and thus be semantic information) independently of a receiver. The example he gives is the Rosetta Stone which held information before anyone could translate it. This is very significant as it implies that information is at least in part objective.
- He also considers whether information can be independent of a producer. For example, environmental information, e.g., paw prints or tree rings. He concludes that it may be used by animals but is not "meaningful" unless processed by humans.

Floridi has a well-articulated concept of information that is very similar to Dretske and also to Mingers' theory that will be discussed later (Mingers 1995a). There is in fact much more to Floridi's work than we have so far discussed – for example the relationship between information and knowledge (Floridi 2010; Floridi 2014), the way in which receivers access information (Floridi 2008b), the existence of information structures (infosphere) (Floridi 2008a), and information as an ethical subject (Floridi 2002a). Some of these will be taken up in the later discussion.

In terms of the evaluation criteria, Floridi's theory is very similar to Dretske, although an issue is that it can be argued that ultimately Floridi is ambiguous over the exact ontological status of information (Mingers 2013). At times he seems clear that information is meaningful data, and therefore objective. At others, he appears to say that information is generated by the receiver and therefore subjective.

Pragmatic dimension

The semantic dimension only concerns the meaning of a message. The pragmatic dimension goes further to consider both the intentions of the sender of the message, and the effects that it may have on the receiver. Mingers (1995a; 1996) developed a theory of information based broadly on Dretske's (and, incidentally, preceding Floridi's (Mingers 2013)) but with significant enhancements. We will not repeat the basics at this point but will concentrate on the developments one of which it to embed it within a general semiotic framework for information systems research (Mingers and Willcocks 2014).

First, Mingers (2001) presented a model of the process by which information is converted into meaning through the brain and nervous system of the recipient. This was based on the neurophysiological theories of Maturana and Varela (1980; 1980b) and theories of embodied cognition (Merleau-Ponty 1962; Varela 1991) (Appendix 1). It is in opposition to the standard representationalist or computational paradigm of cognitive processing in that what can be a message or trigger for the nervous system, and the effects that it has, are structurally determined by the nervous system, not the communication itself. That is not to say that they will be purely individualistic. We have all, through processes of socialization, become structurally coupled to our physical and social environments and so are likely to interpret similar stimuli in broadly similar ways. This model suggests three stages for the receipt and processing of the information carried by signs into meaning and ultimately action. At the first stage, the basic or conventional meaning of the signal/utterance is understood. This is very much an unconscious process carried out routinely by the body and nervous systems – embodied cognition. It is equivalent to Peirce's immediate interpretant (Appendix 1). At the second stage, again largely embodied, we will add to that information the particular knowledge, intentions and concerns that we as individuals have, although again this may well be shared with others (Peirce's dynamic interpretant). Finally, the meaning and understanding generated will lead to an action (e.g., a verbal response, or an activity) or, indeed, no action (final interpretant).

Second, Dretske confined his theory to what he called *de re* knowledge – that is generally perceptual knowledge of our natural and social environment (tree rings, knocks on doors, instruments etc.). He did not include the full pragmatic use of information within human communications. Mingers extended this by bringing in Habermas's theory of communicative action (Habermas 1984; Habermas 1987) which itself was based in part on semiotics (Habermas 1979). With de re

information, the sign or signal carries information about is cause – what created or produced it. This is its propositional content or truth. In considering full human communications from a pragmatic perspective, Habermas takes the basic unit as a speech act (Austin 1962) as part of an on-going conversation oriented towards reaching an understanding.

Habermas argues that a speech act makes four implicit validity claims that can, if necessary, be challenged by an interlocutor and which then need to be justified. The first is *truth*, i.e., that the propositional content is in fact correct, which is the Dretske dimension of information. The other three are *comprehensibility*, *sincerity* and *rightness*. Comprehensibility implies that the speech act (usually but not necessarily linguistic – it could for example be gestural or pictorial) is comprehensible to a competent speaker of the language. This is similar to Floridi's criteria of data being well-formed and meaningful. Sincerity relates to the attitude of the speaker – are they being honest and truthful? Does the speech act genuinely reflect their beliefs and intentions? Or are they behaving dishonestly? Rightness refers to social norms – are the behavioral norms implied by the speech act in fact valid and agreed or are they contentious or not appropriate? With this extended framework, a speech act provides information about not only about factual matters but also about the intentions of the speaker or originator of the communication, and the appropriate social practices and expectations. A good example is the customer reviews of hotels on *Tripadvisor*. This has become extremely important when customers decide where to stay but is it really information? We would have to question not only its factual content but also the sincerity of the reviewer and the cultural expectations that they apply.

To illustrate the pragmatic dimension we use Standing, Standing & Law's (2013) case study of an interior design company in Shenzhen in China. They investigate the firm's use of professional wikis and blogs to share designs and invite comments from fellow designers in order to improve the standard and originality of their designs. All members of the firm were encouraged to share their insights and information as part of their professional practice. The wikis represent an enabling technology for sharing information in this case as they were used to support collaborative design approaches. The authors of the paper use Habermas' (1984; 1987) theory of communicative action to examine the discourse around the sharing of information via the wikis. Communicative action aims at reaching inter-subjective understanding and true consensus through constructive discourse, and emphasizes language and discussion as the medium for reaching understanding. This is achieved by reciprocally raising validity claims that can be accepted or contested in order to coordinate actions and pursue particular aims (Forchtner 2011).

Staff in the design firm were encouraged to say what they thought which equates to the "ideal" speech which Habermas argues is necessary for transformation. However, there were obstacles in achieving an ideal discourse due to structures of habit and ritualism embodied in both cultural and work practices. In addition, open discussion took some time to improve due to the cultural emphasis of maintaining harmonious relationships.

Over time, the introduction of the wiki systems impacted on the behavior and communication of employees in a number of ways. Later interviews showed that staff worked more collaboratively as they began to share more information, experiences and insights. The use of wikis encouraged staff to be more reflective about their work and record their thoughts. Staff spent time evaluating their

colleagues' designs and sharing their insights and eventually the system became a valuable repository of reflections.

If we understand pragmatic information as taking into account the use of information within human communication, in other words social norms, values and intentions, we can evaluate the information exchange in the case study from the perspective of truth, comprehensibility, sincerity and rightness. The information stored and exchanged in the wiki adhered to a professional standard of acceptability and in this respect met a validity test of 'correctness'. The information was understandable or comprehensible to other designers and was communicated with the best intentions and respect, both personal and professional. In essence, the information exchanged in the wiki had embedded social values and expectations. To make sense of the quality of information generated in the case study the social context has to be appreciated that resulted in the information rather than just the information stored in the wikis.

In terms of the theory evaluation criteria we specified earlier, Mingers' theory has the definitional clarity of Dretske and Floridi and is wide ranging. It also moves up to include to some extent the pragmatic aspects of actual information use although it could be developed further in the social sphere.

Social dimension

So far, information has been seen primarily in terms of the individual subject – the sender or receiver of a message – although Habermas's pragmatic view does bring in the idea of social norms. But information also has a social dimension beyond the individual, first because meaning and language is intrinsically social – communications only work because we share a complex system of rules and representations that extends before and beyond the individual. And second because the social and organizational world shapes the information that may be available and the effects that it may have.

We will firstly look at a major German sociologist – Luhmann (1995) who developed a sophisticated theory of society based on autopoietic (Appendix 1), self-producing, communications (Mingers 2002). He envisages two separate but interacting systems – the social system which consists of networks of interacting communications, and the psychic systems of individual subjects' cognitions. What connects these two is the structure of meanings that constitute both cognition and language and which exist outside of, and prior to, the individual consciousness.

Following Mackay (1956), Luhmann sees the primary function of meaning as selectivity (Luhmann 1990) – selecting from a range of possibilities what will become an actuality. Thus in sending a message, the many possibilities - things that could be said, and ways in which they may be said – become reduced to just the one (Shannon-like) that actually is said. Meaning is the relation between what is selected (presenced) and what is not, the selection being characterized primarily in terms of its difference to what was not selected. In this way, meaning generates a selection but at the same time remains related to all the alternatives that were not selected. Meaning thus acts as the gateway to the next instant by opening up further, related, possibilities. Equally, when a communication is received, it selects from within a range of possibilities within the psychic or cognitive domain of the receiver. The particular selection made depends on the existing set of readinesses or expectations, and the resulting experience may change these expectations. It is this change that Luhmann terms information – the surprisal value of a meaning complex for the

receiver's structure of expectations. As with MacKay and Checkland, this makes information subjective, relative to the individual, while meaning is objective, or at least intersubjective. The same messages may generate different information for different people, and a repeated message is still meaningful but not informative. Whilst Luhmann's actual definition of information is basically semantic, it is the fact that he locates this within a sophisticated social theory (Luhmann 1995) and discusses the effects that society's functional differentiation has on communication (Luhmann 1993; Luhmann 2000) that leads us to locate it at the social level.

In terms of the criteria, Luhmann's theory does well. It is well defined in terms of definitions of both information and meaning and can draw on a well-developed sociological underpinning. It is quite general in dealing with both events and language, and explicitly covers the semantic and to some extent the pragmatic levels. It seems to provide a good, theoretically sophisticated, version of Checkland's "information = data plus meaning". The main problem is that it again makes information purely subjective, dependent entirely on the receiver and unable to be stored, carried or processed as normal usage would have it. Information systems would simply be data systems.

Hofkirchner approaches information from a general systems viewpoint – what he calls a unified theory of information (UTI) (Hofkirchner 2013). He begins with the idea of a self-organizing system, that is, a system that is able to configure its own internal structure in response to perturbations from the environment in a manner that is anti-entropic. Humans are prime examples, but so are autopoietic (living) systems generally, and potentially other material systems. Information is then defined as the relation between the perturbing event in the environment and the self-organizing effect within the system. In fact, information in this view is actually a duality – it is both the difference in the environment that perturbs the system (which could be an entity or an event), and the response within the system in terms of a change in structure. Hofkirchner (2014) equates this with Bateson's difference that makes a difference. The "difference" that makes a difference it the perturbation; the making a difference is the build-up of order; and the "difference" that is made is the effect within the system [7].

At the social level, Hofkirchner identifies three hierarchical systems involved in human communicative activity (the "triple-C model")– Cognition, the mental processes of the individual; Communication, coupled information processes between at least two individuals; and Co-operation, where multiple individuals engage in informative processes within social systems to realize common goals. The theory is primarily human-centered. Cognition is the reflexive ability to generate and utilize information involving three stages – perception, interpretation, evaluation (quite similar to Mingers' three stages described above). Communication involves at least two people trying to make sense to each other through symbolic interchange of information. Co-operation is "*that co-operative process, or the result of that process, in which a number of human systems generate or utilize social information, that is information on the level of the social system they participate in*" (Hofkirchner 2013, p. 226).

The social dimension of information can be illustrated with Twitter. Twitter is simultaneously a broadcasting service and a social network, although the social network on Twitter is open as relationships can be unilateral or bilateral. It is argued that Twitter is more an information sharing

[7] McKinney and Roos' (2012) information theory, which they call a theory of difference, is very similar to Hofhirchner's in principle.

tool than a social network tool and has blurred the boundary between social networks and news media by adding 'social' into the cycle of information production, exchange and consumption (Shi et al. 2014). Business research has stressed that firms using Twitter should emphasize community building to improve the chance of successful adoption and use (Culnan et al. 2010). Popular topics at any given time such as political events, sporting events and celebrity news are termed as 'trending' and these trending topics demonstrate how individual communication takes place within and in response to a wider social dialogue.

The social information characteristics of Twitter are many. Twitter combines personal information selection with networks of interacting communications due to the capability to broadcast tweets. Information topics or domains form communities or networks within which each tweet can be understood. With only 140 characters to play with users have to decide upon the message content from a range of possibilities, or things that could be said. Meaning is related to not only what is said but what is not said and a message is cognitively processed by the receiver as being relevant, interesting and novel. The decision to retweet a message, for example, would be made on the value of the information to an individual and to a person's network. Information may be objective on the one hand but intersubjective on the other since people may interpret information in different ways and a repeated tweet message (tweet that includes the same information) maybe meaningful but not informative.

In evaluating Hofkirchner, it is similar in spirit to Luhmann but is more general and less detailed. In particular, it seems so general that it does not really specify what information is. Anything can be an interaction and have an effect but does that therefore make it information? Is a physical or chemical interaction information? It also seems to limit information to human communications but what about all the possible environmental information available to animals? And, the conception of social information seems confusing. If information is the change in a human mind, then what could be social information over and above individual humans? Or does it assume some supra-individual social system that can somehow process information?

Towards a Theory of Information for Information Systems

We have now reviewed a range of information theories at a number of different structural levels. In this section we will pull these threads together to suggest what we consider to be the most appropriate theory of information for IS and other disciplines. In doing this, we will first discuss three of the important questions that arise with any such theory. In particular, is information objective or subjective? Must information be true to be information? What about the problem of the inevitable ambiguity of meaning?

Information as objective or subjective

The theories discussed above differ in many ways, but we feel that the most significant divergence is the ontological one as to whether information is fundamentally objective, existing even if it is not received or observed, or subjective, only coming into existence when data or a message is interpreted by the mind of a receiver. Dretske, Floridi and Mingers argue for the former; MacKay, Luhmann, Checkland and Hofkirchner for the latter. In this paper we argue strongly that information is objective whilst accepting that the same information may well have different meanings or *import* for different receivers. The reasons for this are:

1. If information is to be a purely subjective phenomena, only occurring in the minds of observers, then it means that what we take to be repositories of information – books, newspapers, timetables, websites and above all information systems – cannot contain or process information but only data. When we talk and communicate with each other we can never pass on information since it is not information until it is received, and then it may not be what we intended to transmit. Nothing can contain or carry information until it is interpreted by a human, so the Rosetta Stone had no information until it was translated, tree rings do not carry information until someone looks at them, and the natural world cannot provide information for animals since they are not human. All of this is very much against common-sense and the whole notion of information systems.
2. Accepting that information is objective does not thereby imply that that there are not subjective elements in what different receivers obtain from information. That which the subjectivists characterize as information – the effects of the message on the receiving system – we do not deny, but we simply say that is not information, but rather the meaning or import of the message for the receiver (this will be expanded below).
3. This view of information can be philosophically underpinned by critical realism (CR) (Bhaskar 1978; Mingers 2004). CR distinguishes between the intransitive and transitive domains of science, the former being objective and the latter subjective, or at least intersubjective. The intransitive domain consists of the objects of knowledge, both physical and non-physical, that exist independently of our knowledge of them. The transitive domain is the domain of human knowledge and scientific activity. For us, information is intransitive – it exists even if it is never observed or received – while meaning or import is transitive, being the subjective experiences, beliefs and actions generated by information.

Information as true or correct

The question here is, does information have to be true to be information as Dretske (1981), Floridi (2004b) and Mingers (2013) maintain? Insisting that information has to be true is a very strong assumption not least because of the difficulty of defining and discovering truth (Colburn 2000; Fetzer 2004). In fact we would prefer to use the criteria of correctness rather than truth since it is more general[8] and perhaps less contentious than the term truth.

The basic argument in favor of this is fairly obvious – if we receive a message, say "there is a train to London at 10.00", that is actually false then have we been informed or received any information? It would seem not since if we arrive at the station we will find there is no train. It does not matter if the sender believed there was a train, the reality is there is not. False information is not information anymore that a fake Rolex is a Rolex no matter how much it looks like it. On this view, signals and messages always do transmit information – that which is true about their generation – although it may not be what they appear to transmit.

One argument against this assumption is that we can never discover with certainty what is true or correct. Even critical realism maintains a fallibilist view of knowledge, that we can never prove a theory or belief beyond doubt. Thus we would never be able to determine absolutely if something

[8] In philosophy, truth is usually taken as some form of correspondence between a proposition and states of the world, and generally concerns synthetic (empirical) rather than analytic (definitional) statements. But we would like to include analytic statements such as "a square has four equal sides" which can be correct or incorrect.

was indeed information. A related argument is that we can never make a statement with absolute precision so that it can never be absolutely true, and thus there could never be information if it has to be absolutely true.

Considering the first, we essentially accept it but would distinguish between defining information and warranting a particular piece of information. In other words, information is that which is correct, and much of the time we do indeed transmit information but, if we had to prove the correctness or truth of a particular piece of information, it might not be possible to do it[9]. The second objection is quite serious as it threatens to undermine even the definition of information. Again, we would accept the basic argument that all statements are likely to have a degree of imprecision about them – even the most precise physical measurements have error limits[10]. So, we have to say that correctness, and therefore information, will always be relative to certain limits. For example, an instrument such as a petrol gauge shows the amount of fuel in the tank perhaps to the nearest liter but still provides information if it is working correctly[11]. If we were told there is a train "about 10.00" we might consider that correct if it was actually between 9.50 and 10.10, but not if it was 10.30.

To summarize, the actual information transmitted is always that which is correct but it may be difficult in a particular case to prove unequivocally that it is so. And, information always has a degree of imprecision about it and correctness can only be judged relative to those limits.

Information and the ambiguity of meaning

When we consider full human communication, it soon becomes clear that there are huge amounts of potential ambiguity in the meaning of a speech act. Given that meaning is necessary for, but not the same as, information this ambiguity may well affect the information available in messages.

In order to be clear we will consider a simple message from A to B like "I did not see him at the meeting yesterday" (AB). First, we need to follow Mackay (1969) and distinguish between at least three different meanings attached to this message: the intended meaning of the sender (intent), the meaning generated in the receiver (import), and the conventional meaning of the message (intension and extension). Now, theoretically for us to be able to say that (true) information has been transmitted from A to B it would be necessary that all three meanings coincided so that the receiver's import was indeed the sender's intent. Often, this is the case, especially with simple, direct communications but equally it may not be and the import may be more, less or just different from the intent.

Ambiguity is generated because meaning is underdetermined in a variety of ways. We will discuss three forms – levels or contexts of communication, indexicality and polysemy.

As mentioned above, Floridi pointed out that there were several levels of what he called data neutrality. We have extended this idea in Table 2.

Semiotic Level	Function	Examples

[9] This is analogous to "knowledge" which is conventionally defined as "true, justified belief" and so is equally dependent of proving truth.

[10] Even discrete counting cannot be perfect – are there really "nine million bicycles in Beijing" to quote a Katie Melua song?

[11] If it is not working properly then it does not transmit information even if, by coincidence, it happened to display the correct reading.

Empiric	Transmission	Speech, handwriting, gestures, printing, electronics (SMS, email, social media etc.)
Syntactic	Data representation	Binary, digital, figures, maps, diagrams, pictures
Semantic	Expression of meaning	Same thing said differently; tone of voice body language, sub-text, emotion
Pragmatic	Purpose/effects	Illocutionary and perlocutionary effects, deception
Social	Context	Norms, functions, context, distortion, suppression, the media

Table 2 Levels of Independence in Communication

If we consider the implementation of a particular communication, there are multiple choices at each of the semiotic levels and they can all potentially affect the meaning. Messages may be transmitted in many ways: physically, virtually, electronically, and this will affect both the meaning of the message and the way it is received (Nellhaus 2010). Consider for example the effects of being sacked or breaking up a relationship via text message. Syntactically, the same data can be represented using a variety of different coding systems, for instance if we look up a particular location in *Google* we could get physical coordinates, a map, a satellite photo, a street view or a description.

Semantically, we can say the same thing in a variety of ways which may have different connotations (see below). We can also modify the overt meaning by tone of voice or body language thus expressing emotion. This is one of the well-known problems of text or email messages which led to the development of emoticons (Daft and Lengel 1986). Equally, what is *not* said may be a highly relevant part of the meaning (as mentioned above, absence can also be a source of information). For example, in the AB message, the sub-text could be "I wish I had seen him" or "He should have been there".

At the pragmatic level we are concerned with the intentions of the sender and the effects on the receiver of the message (Austin 1962; Habermas 1979; Searle 1969). Is it to be interpreted as a question, an order, a request or just a description? Is the speaker being sincere or are they being strategic or deceptive? Finally, the social context of the communicative event sets the normative expectations for what is or is not appropriate, or the way in which the communication may be interpreted. For example, an intimate health question would be inappropriate outside a clinical situation. An accusation of murder would mean different things in a court as opposed to a theatre[12].

Indexicality in this context refers to messages in real conversations that often use underdetermined terms such as "he" or "then" where the referent should be obvious from the prior conversation or the context. In the example you would only know who was not at the meeting from a previous message. This works fine where everyone involved is fully aware of the whole conversation but can cause misunderstanding when the term could refer to multiple people, or the recipient forgets or was not part of the conversation. This can happen in email trails only part of which gets copied to later recipients. It is an example of the more general view that language is always "situated" (Suchman 1990), i.e., its meaning is always heavily dependent on its context.

[12] This is not confined to humans - experiments demonstrate that animals' communicative actions are also context dependent. E.g., a recent study of male chickens (Smith and Zielinski 2014) showed that they issued warnings about predators when females were present but *did not* in the presence of competitor males.

Polysemy refers to the fact that signifiers, e.g., words, often have multiple meanings which may or may not be related (Ravin and Leacock 2000). Equally, the same signified (idea) may be expressed in different ways, each of which may have additional connotations. Some examples are: "I put on a light coat" could mean the coat was not heavy or not dark. "I was close to the bank" could refer to a financial institution or a river bank. Sometimes the ambiguity is not in a particular word, but in the sentence as a whole – e.g., "they are flying planes", "time flies like an arrow, fruit flies like a banana" or the well-known book title, "Eats, Shoots & Leaves" (Truss 2003). Often, the appropriate meaning can be determined from the context but, as with indexicality, it can sometimes simply remain indeterminate and is certainly one of the biggest problems with automatic language understanding.

What this shows is that full linguistic human communication is incredibly complex and is in continual danger of misunderstanding and miscommunication. Does this thereby undermine our conception of information as the true propositional content of meaningful data? We need to distinguish carefully between meaning and information. As Luhmann (1990) says, humans are meaning processors. We exist in and with meaning and are continually generating and interpreting meanings. Generally, but not always, the meanings are successfully transmitted and, if the meanings are also true or correct, then information is transmitted as well. Ultimately, if meaning and information were not transmitted regularly then our very complex and interconnected society would simply break down.

A theory of information as true and objective

Our information theory will be very general beginning with simple marks, differences or distinctions, as with Bateson (1973a) and Spencer Brown (1972) (Appendix 1), and move up to full human communicative action.

Events that occur in the world make a difference to it, and the difference can be taken as a mark or token of the event. Information, at its most general, is the relationship between a token, sign or message and the event that caused it or the situation it describes.

Information *is the propositional content of signs. It is that which could be inferred about states of affairs given that the sign has occurred, but could not be without the sign.*

Data *is a collection of signs put together for a purpose. If it is well-formed and correct, it will carry information.*

Information records what must be the case given that the difference or token has occurred. It exists whether or not it is ever observed. Information is always true although it might be different from that which the sign purports to carry. In Table 3 we consider this at different levels, and we also point out at each level what might prevent the signal from carrying information or being informative.[13]

[13] Information must ultimately be manifest in physical differences. For humans these will be accessible through the senses (sight, sound, taste, touch, smell) but there are differences, and therefore information, that exists in ranges beyond our senses, e.g., high or low sounds, infra-red or ultra-violet light.

Levels of information			Reasons for it not to be information		
Form	**Dimension**	**Example**	**Problem**	**Example**	**Name**
Differences, marks, tokens (indexical signs)	Environmental / physical	Tree rings, cloud chamber tracks, animal tracks, door knock, geological strata	No difference or causal relation	Randomly generated differences, hard disc wiped clean	Void or blank
Signs involving some form of coding, eg iconic signs	Syntactic	Maps, icons, instruments, numbers, letters, graphs and charts, pictures	Not well-formed	Pdf file with wrong coding	Garbage
Signs that are purely symbolic	Semantics	Natural and artificial languages, websites, databases	Well-formed but not meaningful or untrue	"Green dreams sleep furiously"	Gibberish or mis-information
Speech acts, conversations, communications	Pragmatics	Questions, commands, requests, commitments	WFD, meaningful and true but not sincere or appropriate	Lies, deviance	Dis-information

Table 3 Levels of Information and Ways they may not be Informative

We begin with events in the material world that occur[14] and leave traces in the form of physical differences. These traces may be short-lasting (particles in a cloud chamber) or long-lasting (rock strata). For there to be no information the differences must be random, or be erased. These traces or tokens can be false and therefore not carry the information they would appear to, for example false trails or decoy ducks. They do not constitute data in themselves but data can be created from them. For example, tree rings themselves are not data but measurements of them are.

At the syntactic level, signs have a degree of conventionality or coding but still retain a connection to their referents. For example, thermometers and instruments generally, maps, icons (including computer icons), graphs and charts or clocks. They may include numbers and letters. The relationship is generally one of similarity or contiguity (metaphor or metonymy). To be able to carry information they must be well-formed syntactically (wfd). Examples where this is not the case might be a map that has been colored wrong or a pdf file that has the wrong font generated and is unintelligible.

At the semantic level, we reach sign systems that are fully symbolic and disconnected from their referents. Examples are natural and artificial languages, websites or databases. This is the level at which meaning becomes of primary concern because of the arbitrary nature of the signifiers which have to acquire and maintain their meanings within complex social processes. Meaning, in general, has two dimensions – sense (intension) and reference (extension) (Frege 1952) – what the term connotes in relation to other terms, and what it denotes as objects or entities. To convey information, a message must be meaningful both in its individual terms and as a whole. The example

[14] We follow critical realism in separating the domain of actual events from the domain of the generative mechanisms that cause them (Mingers 2004)

in Table 3 shows a sentence in which each word is meaningful and it is grammatically correct yet it is not meaningful as a whole. The problem of ambiguous meanings has been discussed above.

At the pragmatic level, we bring in information about more than just the propositional content of the message. Speech acts carry information about the sincerity and emotionality of the speaker, and also the social or normative rightness of the speech act and its content. This leads us to consider the process of rational argument and what Habermas calls discourse ethics (Habermas 1990). Ethical and moral behavior should be based on norms and values that are arrived at through genuine, participatory discourse and debate thought the "force of the better argument" rather than through the exercise of power or self-interest. This ultimately relies on (true) information and honest communications (Mingers and Walsham 2010).

We do not see the social level as another type of information; hence it is not included in Table 3. Rather, we see social and cultural systems as both enabling and constraining the flow of information. On the one hand, it is only through structures of meaning at the social level, which we all share, that it is possible for us to communicate at all as semiology has demonstrated (de Saussure 1960 (originally 1916); Mingers and Willcocks 2014; Peirce 1907). On the other, it is clear that information has value and generates power and therefore it is continually the subject of forces that try to limit or channel it in particular directions. This is beyond the scope of the paper but for a range of theoretical views on this see Webster's (2006) *Theories of the Information Society*.

Conclusions

This paper has addressed the foundational issue of the nature of information. In the first part of the paper a range of existing information theories were presented across the basic dimensions of the physical, syntactic, semantic and social. They were evaluated in terms of their definitional clarity, their practicality for information systems and their comprehensiveness. On the basis of this review, the second half of the paper made a proposal for a general theory of information suitable for information systems. It also reviewed three significant questions for any such theory: whether information was subjective or objective; whether information had to be true to be information; and the problems of the inherent ambiguity of meaning.

Although this paper has been wide-ranging, there is much that it has not been able to cover. In 2004, Floridi published a paper titled "Open Problems in the Philosophy of Information" (Floridi 2004a)[15]. In the paper he covered five main areas: analyzing the concept of information, semantics and information, artificial intelligence and information, information and nature, and values or ethics and information. Within these five areas he highlighted *eighteen* significant questions. Of these, we have touched on perhaps five or six in this paper. Many of the others are both interesting and of importance for information systems. We would like to think that IS researchers could make contributions to these debates. Perhaps the most important, in an age when our most personal and private information can be electronically harvested almost at will, are the questions about computer and information ethics.

[15] Crnkovic and Hofkirchner (2011) updated it in 2011

Appendix 1 Concepts Relevant to Information Theory

1. Peirce's theory of semiosis

Peirce developed his theory of semiosis throughout his work – it is highly complex and changed as it developed (Peirce 1931-1958). For a general overview see Short (2009) and for its use within IS see Mingers and Willcocks (2014). The heart of his theory is the semiotic triangle. A sign consists of three inseparable components – the token itself (the representamen) which could be an icon, an index or a symbol; the object, i.e., that which the token represents; and the interpretant, i.e., the meaning generated by the sign for the receiver. The sign is thus stands in place of something for someone. Note that Peirce did not restrict semiosis to humans – signs may be used by animals and even plants (Noth 2014).

He further distinguishes between the immediate object which is the general object denoted by that sort of sign ("bus"), and the dynamic object – the particular bus being referred to. And, the immediate interpretant – the general sense of the sign ("form of public transport"), the dynamic interpretant – the effect that the sign has on the receiver ("that's my bus"), and final interpretant – action running for the bus.

2. The semiotic framework

Building on Peirce's semiotics (see appendix), Morris (1938) characterized semiotics in terms of three dimensions – the syntactic, semantic and pragmatic. The syntactic dimension covers all the formal relationships between signs within a language or sign system including non-linguistic and non-human systems. This is what we might generally see as the grammar of a linguistic system. Semantics covers the actual meaning of terms within the system – how terms acquire their meanings and how they relate to what they represent. This covers both sense and reference in Frege's (1952) terms, or interpretant and object in Peirce's terms. Pragmatics covers the origin, use and effects of signs, or speech acts as Austin (1962) would call them, in other words, the practical use of communications in real situations (Habermas 1979).

This basic framework was enhanced by Stamper (1991). He added the social level above the pragmatic to reflect the use and effects of semiotics within organizations and society beyond the individual sender or receiver. Below syntax he added two levels. At the bottom is the physical level of actual marks and differences in which codes are embodied - "no it without bit" – and in which we would include fundamental atomic and quantum states. Next up is the level of empirics which involves the storage and transmission of the physical code tokens.

In the text we use a slightly modified version of this framework.

3. Shannon and Weaver's mathematical theory of information

Shannon was an engineer who was interested in the transmission of information from a source to a receiver, particularly in terms of accuracy and cost. He developed a measurement for the *amount* of information that a particular code or message could contain, developing earlier work by Hartley (1928). It was published in a paper with Weaver (Shannon and Weaver 1949). He recognized explicitly that his theory did not deal with the content of messages (semantics) but only their possible structure (syntax) and transmission – "These semantic aspects of communication are

irrelevant to the engineering problem" (p. 3). Nevertheless the theory has become widely adopted and has formed the basis for other, semantic and physical theories.

The fundamental idea is that the amount of information depends on the number of possible messages or symbols that are available, and their relative probabilities. The more possible symbols or messages, and the more equally likely they are, the greater the amount of information conveyed by any one. This is measured in the formula

$$H = -k\Sigma p_i \log(p_i)$$

P_i is the probability of symbol i; k is a constant to define the units; log is generally to the base 2. The minus sign ensures that the result is positive. To give a simple example, taking k as 1, a binary digit has an information value of 1 (assuming 0 and 1 are equally likely); a decimal digit has an information value of 3.32, so a decimal symbol can carry more information (reference more states) than a binary one.

So far this seems reasonable – the more possible messages there can be, and the more equally likely they are, the more information the receipt of a particular message will convey. This also relates to the value of information. Suppose there is a horse race with many, equally good, horses. The odds on any particular horse will be high and information about the winner would be worth a lot. In comparison, if there are only two horses, and one is better than the other, the odds would be low, and the information would be worth little.

Shannon also linked information to the physical concept of entropy which, as it happens, has an identical formula. Entropy measures the amount of order or disorder in a physical system in terms of the number of possible states and their probabilities. Thus, a disordered system with many equally likely states has high entropy (and information) while an ordered system with a small number of differentially likely states is low entropy and low information. However, this equation between information and entropy is controversial (Muller 2007), for example entropy has defined units (kelvins per joule) while information is dimensionless.

Moreover, there are counter-intuitive implications. Languages such as English are generally well structured – letters and words are not equally likely, they are often quite predictable and have high redundancy. This means that they carry *less* information than random strings of letters or words. Equally, would we not usually say that a highly ordered or structured system (low entropy) contained more information than a random one? One of the other founders of cybernetics, Weiner, also defined information in a similar way but with a reversed sign so that it is equated with negative entropy or "negentropy" (Weiner 1948).

4. Bateson's information as "a difference that makes a difference"

Also tracing its origins in cybernetics, although unrelated to Shannon and Weiner's work, is Gregory Bateson's idea that information is a difference that makes a difference. For Bateson, the fundamental characteristics of the macro physical world are differences – differences in physical qualities – light, sound, texture etc. – which are then endlessly transmitted and transformed circularly.

"A 'bit' of information is definable as a difference that makes a difference. Such a difference, as it travels and undergoes successive transformation in a circuit, is an elementary idea". (Bateson 1973b, p. 315)

Between any two things, or between a thing and its environment, there are an infinity of differences. Only particular ones with be selected by, or impose themselves on, and observer and thereby become differences that are noticed; differences that make a difference. In terms of Korzybski's (1933) map and territory, only certain of the differences in the territory get inscribed on the map, and these are what becomes information.

5. Spencer-Brown's *Laws of Form*

The *Laws of Form* is the title of a book by G. Spencer Brown (1972). In this unusual work, he claims to have explored the fundamental laws of thought that underlie logic and Boolean algebra. His starting point is the idea of a simple mark or distinction that separates off one thing from everything else. Imagine drawing a circle on a blank page. Once this has been done, it splits the void or blank space into two parts and allows us to point to or indicate one or other of the two spaces – the inside or the outside of the circle. This is the primary distinction. From this initial act of distinction, he claims two axioms result. If we were to draw another distinction (circle) it would have to be outside or inside the first one (assuming it was not allowed to intersect it). In the first instance, we are simply making the same distinction again and so:

"*The value of a call made again is just the value of the call"* (Axiom 1).

But, if we draw it inside the circle we are crossing the boundary into the inside space. In this case:

"*The value of a crossing made again is not the value of the crossing"* (Axiom 2).

From these to axioms, Spencer Brown develops an elegant calculus and algebra that is able to represent both Boolean algebra and the propositional calculus.

We can see immediate connections with Bateson's difference that makes a difference and Dretske's digitalization of the analogue.

6. Autopoiesis

Autopoiesis is a theory developed by biologists Maturana and Varela (1980a), (Mingers 1995b) that explains the nature of living systems. "Autopoiesis" means self-producing or self-constructing and the theory suggests that living organisms, a single-celled amoeba being a paradigm example, are systems that continually produce their own components in a circular, organizationally closed manner. Whilst they do interact with their environment, ingesting raw materials and excreting waste, their primary activity is producing the very components that constitute them in the first place. A consequence of this organization is that autopoietic systems are relatively autonomous such that external interactions only trigger or select internal changes but do not determine them (structural determinism).

Maturana and Varela (Maturana 1980; Varela 1991) also characterized the operations of the nervous system (and therefore cognition) as being organizationally closed such that relative states of nervous activity followed from and led onto further such states. Again, external interactions (perceptions)

can only trigger particular changes of state, not determine them. In terms of information, this means that communications could not simply impose or inject information into the mind of the receiver, all they could do is trigger or select particular neuronal changes dependent on the previous state of the system. This supports an embodied rather than representationalist view of cognition (Mingers 2001).

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