Signaling games: thought experiments and Information Systems

Completed Research Paper

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Abstract

Within this paper we use the thought experiment of a signaling game to demonstrate how information can be seen to evolve as a complex, systemic accomplishment amongst a community of actors. An example from animal communication studies is first used to highlight the relevance of this thought experiment. We then unpack various ideas about the nature of information in terms of aspects of the signaling game. We also demonstrate the way in which this thought experiment helps clarify the relationship between information and that of agency, embodiment, intentionality and materiality. This leads us to demonstrate the application of the concept of a signaling game to a class of information system ubiquitous in the human sphere: that of an effective manual system.

Keywords: Thought experiments, Signaling game, Information, Information system

Introduction

Within the current paper we wish to propose a novel 'method' of research (at least as far as Information Systems is concerned) – that of the thought experiment (Cohen 2005). Thought experiments are of course considered a valid form of doing and presenting 'research' in disciplines such as philosophy. But such abstract 'experiments' are also well-utilized in the natural sciences, in areas such as theoretical physics and theoretical biology. For instance, Einstein formulated many of his theoretical insights by conducting thought experiments of various kinds. One famous experiment involved him thinking about what would happen if someone was travelling in an elevator accelerating toward the speed of light. This enabled Einstein to formulate some classic features of his theory of relativity. In contrast, Axelrod (2006) has used the thought experiment of a prisoner's dilemma game to argue for the evolution of cooperation as an effective survival strategy amongst species.

We want to use this paper to demonstrate some of the power of the thought experiment for the discipline of information systems. We want to use a particular thought experiment adapted from the philosophy of convention (Lewis 2002) and the philosophy of information (Skyrm, 2010) and use it to better explain how information is not 'stuff' but a complex accomplishment of a community of actors. Information is also not an accomplishment just available to the human species. It has evolved as a selective strategy within both simple and complex organisms (Dennett 1996) and is related to the need to achieve

coordinated behavior by organisms in the face of a turbulent environment (Maturana and Varela 1987). Information in this sense can be seen as an evolutionary phenomenon critical to the 'survival' of a particular community of actors. More precisely, information is very much related to the accomplishment of shared intentionality (Tomasello and Carpenter 2007), which has evolved because of the 'payoffs' this accomplishment provides to social organisms, such as ourselves.

Thought experiments such as Maxwell's Demon and Schrödinger's cat have been used within disciplines such as theoretical physics to explore the relationship of a particular conception of 'information' to issues such as entropy and quantum indeterminancy. However, the particular way of methodically unpacking the concept of information used here and as it relates to issues of organization is new to information systems. The thought experiment considered here is not just useful for unravelling where information comes from and what its nature involves. In doing so, the thought experiment helps better illuminate a number of issues that are much-discussed in the information systems literature, but frequently not in a very clear manner. For instance, our thought experiment offers a useful way of unpacking the relationship of information to that of agency (Rose, Jones and True, 2005), embodiment (Mingers 2001), intentionality (Searle 1983) and materiality (Leonardi and Barley 2008).

We build our thought experiment using the idea of a sender-receiver game (sometimes referred to as a signaling game), first formulated by Lewis in his book on the nature of convention (Lewis 2002). This idea is taken up by Skyrms (Skyrms 2010) in his book on the philosophy of language. We then discuss a case from the area of zoosemiotics (Sebeok 1972) that can be explained in terms of this particular thought experiment. This leads us to unpack the core elements from the experiment that are needed to frame some of the universals of information.

Our argument then builds by considering how a particular type of information system, found in the human sphere, can be made sense of in terms of the idea of a signaling game – this is the class of information systems that Lederman and Johnston (2011) refer to as effective manual systems. Such ways of organizing are particularly interesting because they eschew the use of digital computing and communications technology. Instead, they involve the articulation of material and highly visual artefacts such as manual whiteboards, magnetic tokens, post-it notes, cards and strips of paper. Such manual systems are effective and viable within contemporary settings because the very materiality and highly visual nature of the artefacts used within these ways of organizing offer certain affordances (Gibson 1977, 1979) to actors which are not easily reproduced within current digital technologies.

We set up a scenario in which both students and practitioners of Information Systems are required to 'design' an effective manual system for a simple organizational situation. We then unpack this scenario as a signaling game, and in doing so, make better sense of what an information system constitutes, but also what the proper design of such systems should constitute. We conclude with a look at what our thought experiment of the signaling game contributes to understanding issues of agency, embodiment, intentionality and materiality, at least as these phenomena are seen as problematic within the discipline of Information Systems.

Thought experiments

The Stanford Encyclopedia of Philosophy considers thought experiments to be '*devices of the imagination used to investigate the nature of things*'. A thought experiment (gedankenexperiment) begins usually by portraying the features of some theoretical situation. It then 'experiments' with this situation, typically by thinking through its' consequences. Therefore, thought experiments normally apply subjunctive reasoning – '*what might happen if X…*' or '*what are the natural consequences of X?*'

Thought experiments are much used in theoretical physics. For instance, the thought experiment typically referred to as Schrödinger's cat was famously used to explore the consequences of quantum indeterminancy. Similarly, Maxwell's demon was used to explore certain consequences of the second-law of thermodynamics. Finally, Einstein's elevator, as we have mentioned, was successfully used to expand upon the notion of relativity. However, thought experiments have a long and established history within philosophy, dating back to Socrates and Plato (Cohen 2005). Some have argued that philosophy would not be philosophy without the thought experiment (Dennett 2014). Thought experiments are also conducted frequently in professional disciplines such as law, where they are typically referred to as hypothetical cases.

Thought experiments can be broadly categorized as either destructive or constructive. Destructive thought experiments are critical in the sense that they are built to demonstrate the fallacy of some theory, situation or position. In contrast, constructive thought experiments are apologetic in the sense that they are constructed to demonstrate the truth of a particular theory, situation or position.

Some thought experiments are analyzable as logical arguments, often in the form of *reductio ad absurdum*. But many famous thought experiments are less rigorous and reliant on a background of intuitive reasoning. For this reason, Dennett calls this type of thought experiment an 'intuition pump' (Dennett 2014). Intuition pumps are thought experiments which rely upon the thinker's intuition to develop an answer to a specified problem. If a thought experiment is sufficiently rich then various 'knobs' can be 'turned' within the experiment to see if our intuition holds. Dennett feels that such intuition pumps are a critical tool within philosophy, but he cautions in their use. In a positive sense, the intuition upon which such experiments rely is important for reasoning about complex subjects effectively. But such intuition can equally lead the thinker astray.

We shall build primarily a destructive thought experiment in this paper but use it as a positive intuition pump. In particular, we shall set the thought experiment in terms of a simple game known as a signaling game (Lewis 2002; Skyrms 2010). We shall then turn various 'knobs' on this intuition pump to demonstrate that generally held conceptions of the concept of information, which are still very much used within disciplines such as information systems, are fallacious. As we shall see, this particular meta-theoretical 'game' is particularly interesting because it can not only be used for our purposes to build a destructive thought experiment. It can also be used as a constructive thought experiment. We shall demonstrate that we can use the signaling game to highlight, through the application of certain intuition applied to this 'game', not only what information is not; we can use it to point at what information and the consequent concept of an information system must logically constitute.

Signaling games

Within this section we consider a thought experiment which shows how what we think of as information arises not through conscious 'design' but through spontaneous patterns of inter-action performed by a community of actors in relation to states of a particular environment (world).

Consider the minimal case of a sender-receiver game in which we have two actors (O_1 and O_2), two states of the world (S_1 and S_2) and two acts that can be taken in response to these states (A_1 and A_2). One actor (O_1) observes the state of the world and decides to send one of two possible messages (M_1 or M_2) to the other actor (O_2) who is the receiver of the message. The receiving actor (O_2) cannot directly observe the state of the world sensed by actor O_1 but can choose to perform one of two acts (A_1 or A_2) in response to the message it receives.

The actor O_2 having acted, both O_1 and O_2 receive some 'payoff'. Consider the simple situation where there is exactly one 'correct' act for each state of the world. Both actors receive a positive payoff if the correct action is chosen following transmission and receipt of some message – otherwise they receive a negative payoff.

Figure 1 visualizes the major elements of this thought experiment. Actors (O_1 and O_2) are represented as cyclical entities. By this we are attempting to signify that an actor is a self-organizing system (Maturana and Varela 1987) – it is continually reproducing its internal environment in continuous interaction with some external environment. Let us simplify and assume that this internal environment is particularly concerned with implementing what Dennett (1996) refers to as decision strategies – making choices between alternative courses of action. Actors are also embodied (Varela, Thompson and Rosch, 1993)(Mingers, 2001) meaning that an actors' agency involves interaction with its external environment, and that such interaction relies upon two critical forms of apparatus making up the 'body' of the actor: a sensory apparatus and an effector apparatus. A sensory apparatus is made up of a series of sensors which continually monitor differences in the state of the external environment. An effector apparatus consists of a series of effectors that allow the actor to perform instrumental action in relation to this external environment – to manipulate 'structures' within the external environment and through so doing to change the state of the external environment.

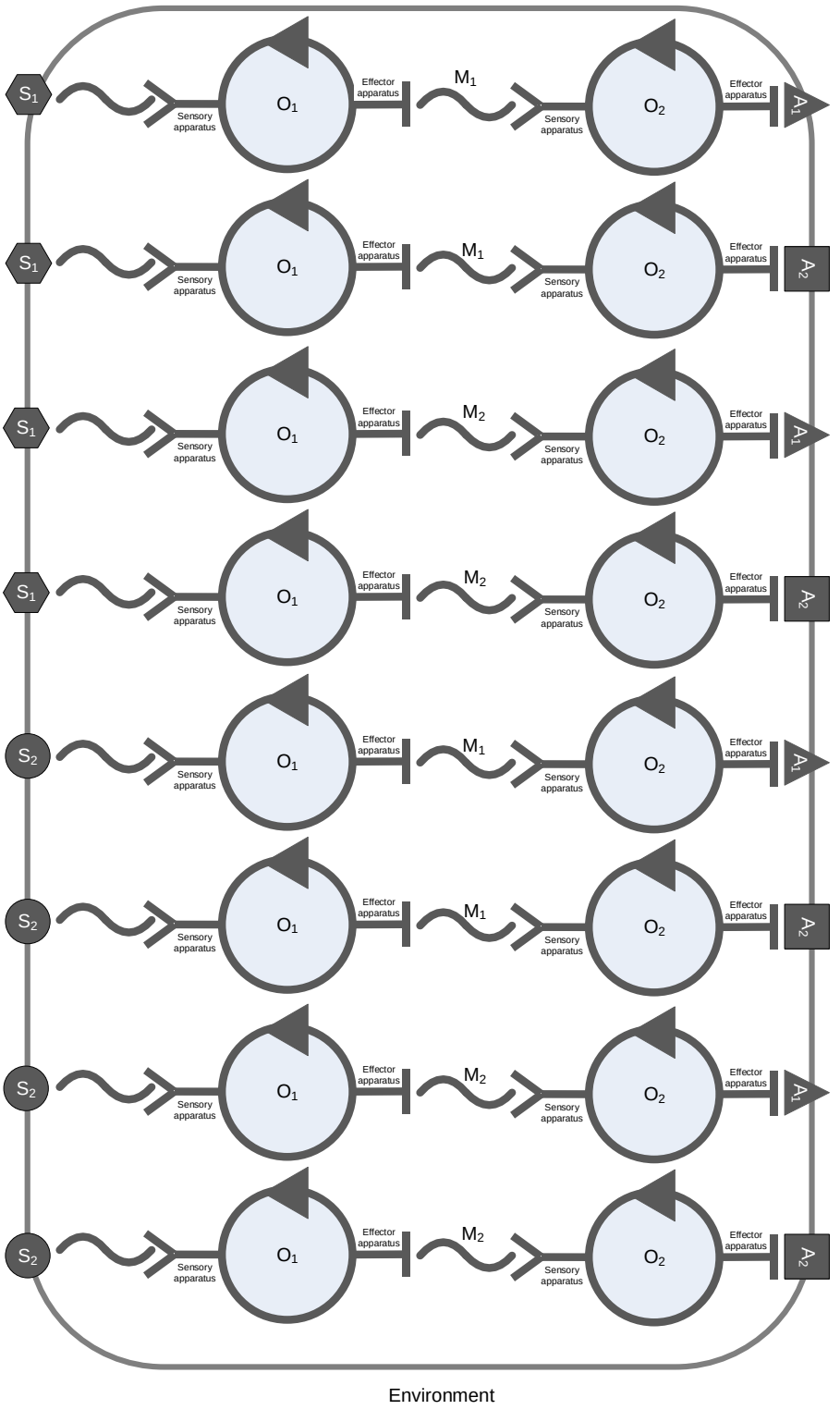

Figure 1. A simple signalling 'game' as a thought experiment

Hence, the sensory apparatus of actor O_1 enables it to discriminate between state S_1 and state S_2 of the external environment. Some decision strategy implemented within its internal environment enables actor O_1 to decide either to produce message M_1 or message M_2 using some effector within its effector apparatus. This message changes the state of the external environment monitored by actor O_2. The message, or more precisely the signal, is picked up by a sensor within the sensory apparatus of actor O_2. A decision strategy embedded within the internal environment of this actor enables it to choose either to effect action A_1 or action A_2.

The entire range of patterns of order corresponding to this thought experiment is laid out as a sequence in figure 1. It can be expected in this 'game' that the actors will eventually settle upon some system of equilibrium where particular messages are always associated with particular states of the world and actions taken. This will occur because the association between particular messages and actions will be reinforced by positive payoff. In such cases the association amounts to the establishment of a convention (Lewis, 2002). For instance, a convention might become established in this manner between the state of the world S_1, the message M_2 and the action A_1. In other words, whenever one actor observes S_1 it emits M_2 and all receiving actors of this message effect action A_1.

An example of a signaling game from zoosemiotics

The thought experiment of the sender-receiver game described in the previous section has been proposed as a useful meta-model for theorizing about the evolution of sign-systems amongst many social animals, including humans. Consider the case of the prairie dog (Slobodchikoff, Perla and Verdolin 2009) which are formally classified as rodents within the squirrel family, Sciuridae. There are five species of prairie dog: black-tailed, Gunnison, white-tailed, Utah and Mexican. Gunnison prairie dogs are the most studied and live in the 'four corners' area of the South Western United States - a boundary area between the states of Arizona, Colorado, New Mexico and Utah. Prairie dog colonies are made up of a number of distinct groups that defend territories. These groups, sometimes referred to as clans or coteries, occupy an area consisting of one or more burrow openings, an underground burrow system and the food resources growing within the territory. Territorial boundaries are defended by all members of the territorial group, which can vary in size from one individual to several males and females.

As far as their sensory apparatus is concerned, prairie dogs have good sight and hearing. They have dichromatic color vision, meaning that they see well in the blue and yellow parts of the visual spectrum, but not well in the red range. They can also hear sounds in much the same auditory range as humans. Prairie dogs use a number of different parts of their effector and sensory apparatus to communicate. They communicate through sounds such as alarm calls, through visual signals such as wagging of their tails and standing upright in an alert posture; they also seem to communicate through the use of olfactory and odor cues given off by glands situated both in their anus and in their faces.

Alarm calls are by far the most well studied forms of prairie dog communication, particularly amongst Gunnison prairie dogs (Slobodchikoff, Perla *et al* 2009). The alarm calls comprise loud and often repetitive vocalizations that sound similar to certain forms of bird call. Such calls are given by one or more prairie dogs within a colony when a predator is detected. A particular type of call produces a distinct escape response on the part of other prairie dogs on hearing the call. All five species of prairie dog produce such calls but the acoustic structure of these calls varies between species.

In close studies of the behavior of Gunnison prairie dogs a number of clear patterns of order are evident, which may be expressed as a series of decision strategies. Observation suggests that they employ something like the following set of decision 'rules': IF predator-call is 'human' THEN run to burrow AND perform a colony dive (all animals within a colony dive into their burrows); IF predator-call is 'hawk' THEN run to burrow AND perform a limited dive (only those dogs within flight path dive into burrows); IF predator-call is 'coyote' THEN run to burrow AND stand at alert; IF predator-call is 'dog' THEN stand at alert at your current position.

From the point of view of evolutionary biology, each of these decision strategies makes sense in terms of the likely intentions of the predator denoted by a particular call. Predatory humans with rifles frequently walk around the edges of prairie dog colonies and can shoot any prairie dog from several hundred meters away. An appropriate act to make in response to the presence of such a predator is for the entire colony to run to the nearest burrow and dive inside. In contrast, red-tailed hawks stoop with great speed to capture

prey. However, once committed to a dive they cannot capture prairie dogs outside of the immediate trajectory of their dive. Hence, an appropriate survival strategy is for the individuals within the flight path of the hawk to run to the nearest burrow and to dive in.

It is noteworthy that the relationship between states of the world, messages and actions appears to be inherited in cases such as that of the warning calls of prairie dogs. Hence, a prairie dog can emit a call for 'hawk' even when it has never previously seen a hawk. These signaling patterns have evolved amongst particular species as a survival strategy.

The payoff of survival has served to select a particular system of equilibrium within this signaling game. Such inherited patterns are typically contrasted with that of arbitrary conventions of signaling familiar within the human sphere. Millikan (1984) argues that a pattern is only conventional if it is reproduced purely by weight of precedent and only if it is unlikely to emerge or re-emerge in the absence of such precedent. Conventional patterns are thus arbitrary patterns. Conventional patterns are patterns for which other patterns might well be substituted except for historical accident.

Within signaling games conducted in the human sphere most, but not all, patterns are conventional in the sense outlined by Millikan. Signaling games amongst the species Homo Sapiens are mostly (but not always) a collective accomplishment reliant upon informative conventions. For instance, in a companion paper (Beynon-Davies, 2013) we have discussed a form of human signaling which appears to be non-arbitrary – that of human emotive facial expression. But whether the pattern is reproduced by genetic or by cultural means does not change the essential features of signaling as a game. We examine some of the consequences of the signaling game for the idea of information in the next section.

Turning some 'knobs' on the intuition pump of the signaling game

One of the key contributions of the signaling game as a thought experiment is that it highlights the fragility of a number of conceptions of information adopted in various aspects of the information systems literature. Each of these conceptions can be considered a 'knob' that we can turn in relation to the intuition pump of the signaling game as described previously. In other words, we can ask questions such as '*What happens if such a conception is taken literally…*'

One particularly prevalent characterization of information is one in which information is seen as fundamental 'stuff' which helps any physical system maintain organization (Stonier, 1994). As such, information is faceted as an objective phenomenon, independent of the actor. Hence, the signals of the Gunnison prairie dog can be analyzed separately from actors and actions. They can be considered as distinctive, invariant patterns produced and re-produced by particular organisms – as data.

This conception underlies the classic approach to information, evident in the theory of Shannon and Weaver (1949). Within 'information theory', information lies in the message, or more precisely in the signal which conveys the message. Information is associated with the degree of order (negentropy) evident in the signal. According to this perspective, as far as the signaling game is concerned, both M_1 and M_2 as signals 'contain' information. But consider the case in which M_1 (a predator-call) is produced by a Gunnison prairie dog (A_1) but sensed by a black-tailed prairie dog (A_2). These two different species of prairie dog emit or effect similar but noticeably different signals in the presence of the same predator. But does it make sense in this situation to think of M_1 emitted by A_1 as still *containing* information for A_2.

Another particularly dominant perspective is to conceptualize information as the act of interpretation of data. In this sense, information is seen to be created within acts of sense-making by individual actors (Boland, 1987). In this guise it is faceted as a subjective phenomenon, bound to the actor. Here, information is bound with some notion of internal processing undertaken within the internal environment of particular organisms. In the case of prairie dogs example, for instance, in-formation is particularly associated with the decision strategy accomplished by particular prairie dogs in the face of predation.

We as humans can hear most of the signal emitted by a particular prairie dog as a predator call. Hence, we may, with much practice, be able to train our ear to identify one predator-call from another. But does the development of such ability equate with being in-formed in terms of this particular signaling game? Even if we train our ear to be able to distinguish one predator-call from another we are unlikely to want to or be

able to take the action that a prairie dog would take. So are we truly in-formed by this act of interpretation?

More recently, information has been considered an inter-subjective phenomenon; reliant on the 'negotiation' of collective or shared intentionality (Searle 1983). As such, information is considered an inter-subjective accomplishment amongst groups or communities of actors. Here, information is related to the shared ways in which actors build an 'aboutness' between sensed aspects of the world and mental states. In our thought experiment, one aspect of such collective intentionality involves the aboutness between the state of the world S_1 and some internal state which causes the actor to emit the message M_2. In turn, message M_2 becomes a state of the world which causes some mental state in all receiving actors, causing them to effect action A_1.

However, there is much debate about whether collective or shared intentionality is necessary for information to exist. Part of the reason we deliberately chose to describe an instance of a signaling game from animal communication studies was to emphasize that information may occur within situations in which the notion of shared intentionality may be questionable. Tomasello and Carpenter (2007) propose that shared intentionality is a defining difference between our species, Homo Sapiens, and the rest of the animal kingdom. '*Shared intentionality … Refers to collaborative interactions in which participants have a shared goal (shared commitment) and coordinated action roles for pursuing that shared goal*' (Tomasello and Carpenter 2007). The notion of shared intentionality is based upon a model of intentional action founded in the idea of a control system or process. Such a control process is composed of a goal to which the system is directed, the ability to act to change aspects of the environment and the ability to perceive the environment so as to know when the state of the environment matches the goal. But shared intentionality can only emerge at the level of what Dennett (1996) refers to as a Gregorian psyche: the level at which a complex inner environment present within some organism is able to 'model' the external environment sufficiently well for the actor to take intentional action.

Finally, we should mention the most radical position which proposes that information does not exist – it is a null concept. Stimulated by the work of Maturana and Varela (1980) and their idea of an autopoietic (self-producing or self-organizing) system, this viewpoint maintains that information is merely a convenience imposed by observers upon situations of behavioral coordination through structural coupling (Beeson 2009). In this sense we observe patterns of order in some situation, such as the ones we have considered in our signaling game. But such patterns merely correspond to invariances between the actions of particular actors in relation to a particular environment. We impose upon such patterning the convenient idea of information being 'conveyed' or 'communicated' as a useful way of accounting for the behavioral coordination which corresponds to such invariances.

This radically materialist account has been accused by some of tending to the extreme position that reality is merely an invention of observers. If we turn this particular 'knob' far enough then the role of both inherited patterns and conventional patterns of signaling are demoted merely to invariances evident within a particular environment of inter-acting organisms. The null account, as we shall see, also has some difficulty in dealing with the role played by external but persistent artefacts, created and used by organisms for signaling purposes, sometimes remote across time and space.

Therefore, the key consequence we take from our thought experiment of the signaling game is that a true account of information must encompass all four viewpoints in one entangled whole. Information is objective because it relies upon materiality. Information is subjective because it is built from agency and embodiment. Information may be inter-subjective when it amounts to the outward expression of shared intentionality. Finally, in terms of each of these conceptions taken independently, information may not exist. Information is not a substantive concept solely reliant upon any component part of our thought experiment. Instead, it is perhaps better to propose information as being a phenomenon which emerges from the continuous exercise or accomplishment of some 'signaling game'.

An anthropo-signaling game

We take the key structural elements of the thought experiment of the signaling game to be applicable not only to situations of 'information' behavior in the animal sphere but also to many examples of such behavior in the human sphere. Games such as Axelrod's prisoner dilemma are used as meta-models or

abstractions in other disciplines to highlight key features present amongst diverse phenomena. It is in this sense that we juxtapose an example from the animal and the human world within this paper.

Within aspects of pedagogy we have developed a simple instantiation of the signaling game to help business students and practicing managers and technologists to make better sense of the concept of information. We have also used this game as an intuition pump for participants to explore the concept of an information system itself, and to turn various 'knobs' on this intuition pump related to the proper 'design' of such systems.

Consider a simple game in which participants are first divided into groups of four. Each of these groups is then given the same task, namely, devising a way of coordinating the movement of units of 'material' through different 'locations' within some organizational 'space'. Such 'material' might correspond to production containers in a manufacturing setting or patients in a healthcare setting or modules in an educational setting. The associated 'locations' might consist of production units, medical procedures or states of module delivery and assessment. Participants are then asked to simulate both the 'material' and organizational 'space' in some way. For instance, participants might assume that some convenient artefact such as a chair corresponds to a unit of 'material' and some area of the room in which the game is played corresponds to the organizational 'space'. They are then told to divide this allocated space up into four smaller areas which should correspond to four 'locations'.

Each group of players is given a small physical whiteboard along with a set of colored magnetic tokens, consisting of 6 red tokens; 6 blue tokens; 6 green tokens; and 6 black tokens (as illustrated in figure 2). Each group is then given the task of designing a scheme for coordinating the work of multiple workers in placing and moving 'material' through different 'locations' using solely this artefact. They are told to assume that workers work within groups together in different time-periods (shift patterns) and that no verbal or written communication occurs between a group of workers working within one time-period and that of another.

The players are further told that the whiteboard and magnetic tokens must be used to accomplish two things. First, inform a group of workers within a time-period how many units of 'material' there currently are at each 'location'. They are told to assume that a maximum of six units of 'material' can be held at a given 'location' at one time. Second, inform a group of workers how many units of 'material' need to be moved from one 'location' to another nominated 'location' within a time-period.

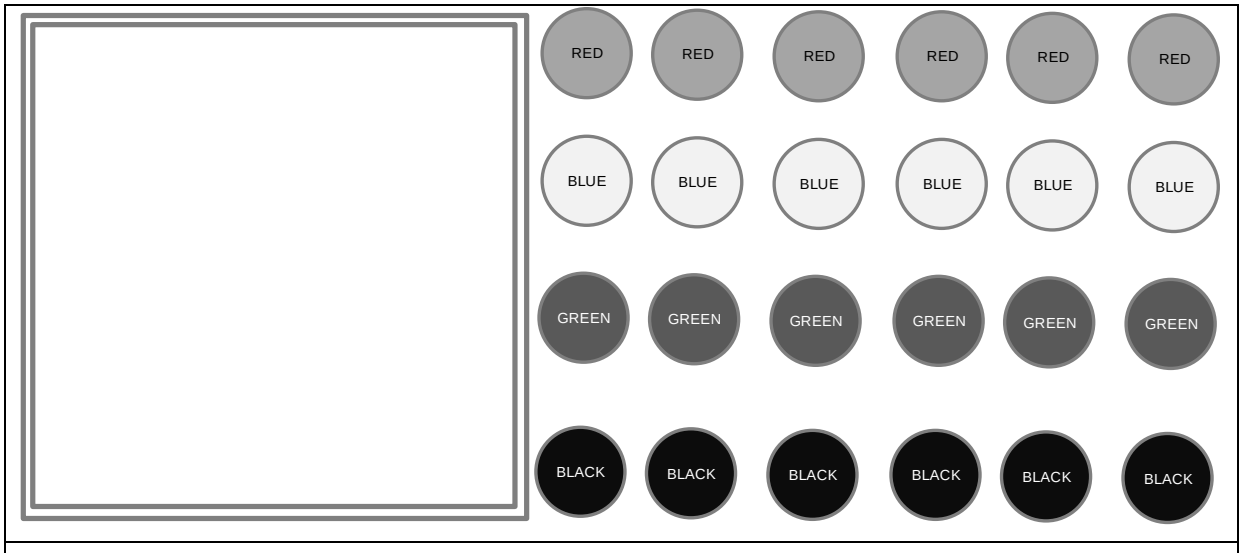

Figure 2. Elements of the anthropo-signaling game

A key constraint is set for the game, namely that no words can be written on the whiteboard. A set of colored pens is available for use by each team but these pens can only be used to draw something, not

write something on the whiteboard. Once they have designed their scheme, participants are asked to test it. In other words, the groups playing the game are required to enact one or more scenarios in which two members of the group act as the group working in one time-period and two members act as the group working the next shift. They are particularly asked to use these scenarios to experiment with signaling both current 'material' positions and intended 'material' positions. Finally, each group is asked to explain their particular 'design' to the other groups playing the game. They are also asked to think about any similarities and differences between their solutions and whether certain 'designs' are better than others in terms of some criteria that they must arrive at themselves.

One design 'solution' readily arrived at by most groups playing this game is to assume that the entire whiteboard represents the organizational 'space'. Four squares are then drawn upon the whiteboard to represent the four 'locations' within the organizational 'space'. Each square of organizational space is then color-coded. Hence, the first location might be thought of as the red location, the second the green location, the third the yellow location and the fourth the blue location. The number of magnetic tokens placed within each box upon the whiteboard can then be used to signal to workers the number of units of material currently at each location. A token which is non-standard for its area can be used to signal that an item should be moved to the area it color codes. Hence, the presence of a blue token in the green box should signal that one unit of material should be moved from the green location to the blue location.

Now consider how this exercise in pedagogy works as a signaling game. The manipulation of a magnetic token by a particular actor causes changes to the physical environment. The articulation of a magnetic token amounts to a change of state to this physical environment of the work situation in question. This change of state is sensed by another actor and serves to signal a particular intent and content to this actor. On the basis of this message, the actor decides to act in a particular way, such as moving a particular chair from one location to another.

The colored, magnetic tokens as well as the whiteboard clearly correspond to significant structures in the environment of the game. Four distinct acts of articulation can be undertaken in relation to these structures - placing a token of color X in a square of color X; removing a token of color X in a square of color X; placing a token of color X in a square of color Y; removing a token of color X in a square of color Y.

The results from particular acts of articulation signal particular messages to participating actors. In other words, and as illustrated within figure 3, an actor A_1 manipulates some physical structure S_1, namely a colored, magnetic token using his/her effector apparatus. The concept of affordance (Norman 1999) refers to a property of a certain structure that allows an actor to perform an action. Two affordances of a colored magnetic token are exploited in the acts of articulation described. The first involves the selection of the token itself, particularly in terms of choice of color. The second involves the token's positionability. A magnetic token can clearly be positioned in relation to other magnetic tokens anywhere upon the whiteboard. It can also be removed from a particular position upon the whiteboard.

The configuration of tokens upon the whiteboard acts as a series of further affordances to actor A_2. In particular, the articulation of structure S_1 is sensed by the sensory apparatus of actor A_2. The sensed physical state of structure S_1 serves to signal some message M_1 to actor A_2. Two aspects of message M_1 are indicated in figure 3. The first aspect specifies its intent (in this case a so-called directive) while the second aspect specifies its content (the location that a unit of 'material' (a chair) should be moved to).

In other words, the physical state of S_1 in relation to the whiteboard indicates not only what the structure refers to in terms of 'material' but what should be done in relation to this 'material'. This means that the message M_1 acts as a further affordance to the manipulation of some structure S_2 within the work environment. Hence, in terms of content the structure S_1 (a magnetic token) refers to a further structure S_2 (a chair) within the work environment. However, the positioning of a particular colored token in relation to the colored squares of the whiteboard signals the intent of the message. A token of color X in a square of color X *asserts* that one unit of material is present at the specified location. The presence of a token of color X in a square of color Y *directs* actor A_2 to move a unit of material from the location with color X to that of color Y.

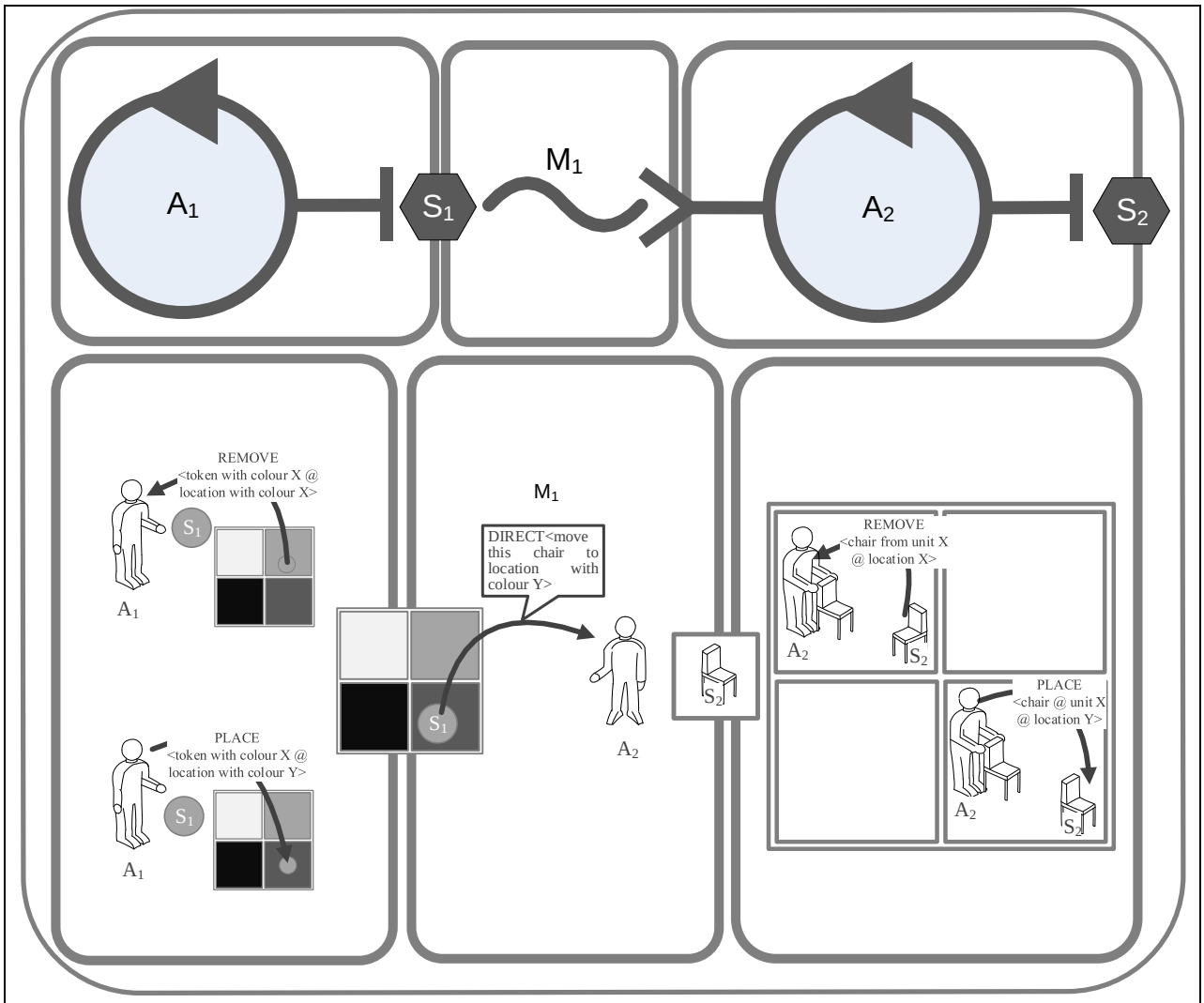

Figure 3. Deconstructing the anthropo-signaling game

Turning some further 'knobs' on the intuition pump

The signaling game described in the previous section is not only meant to encourage reflection amongst participants about the nature of information; it is also meant to encourage reflective practice (Schön 1983), particularly as such practice concerns the use and 'design' of informative artefacts within the workplace. The notion of 'design' in such terms is considered as a process of co-creating narratives of action in relation to particular ways of organizing (Gabriel and Connell 2010). It can also be seen as an attempt to catalyze ways of practical reasoning about the place of informative artefacts within particular situations of work (Statler 2014).

The informative artefacts utilized within the game itself are deliberately simple, comprising a large, magnetic whiteboard and a range of colored, magnetic tokens. Such artefacts are familiar within the philosophy of so-called visual management, which is particularly implemented in terms of ideas of the visual workplace (Grief 1991) and notably through systems of visual devices situated within work settings to communicate with 'doers' – the actual people performing work within these settings (Grief 1991; Hirano 1995; Liff and Posey 2004). The success of visual management is often attributed to the tangibility and high visibility of such artefacts within group work (Galsworth 1997).

However, many of the features for reflection which arise from this game, we believe, are equally applicable to the 'design' and use of much more complex artefacts used for informative purposes within the workplace, namely digital computing and communications systems. Indeed, in many applications of this game we have used the artefacts of the whiteboard and the magnetic tokens as destructive thought experiments; as sensebreaking devices – as ways of breaking down conventional expectations of the place of informative artefacts and revealing the essential place of digital computing systems within particular ways of organizing. These features can be considered as six key 'knobs' that need turning in relation to this particular intuition pump.

Information systems emerge in action

In treating the way of organizing described in the previous section as a signalling game we can ask not only where is the information within this way of organizing (as we have done)? We can also ask where is the information system within this particular way of organizing work? The information system is clearly not in the 'technology'. Indeed, our example deliberately does not involve any information technology, at least as conventionally conceived. The information system is also not in the work itself nor does it solely lie in aspects of communication, as we have portrayed it. This leads us to suggest that assigning the concept of an information system to the category of one or more of the substantive elements of a signaling game, which each contributes to some way of organizing, is to commit what Ryle (1949) refers to as a category mistake.

A category mistake is an ontological error. It involves instantiating something as belonging to a particular category or class when this thing actually belongs to a different category or class. Within disciplines such as Information Systems, where the use of the term information system is of course commonplace, there appears to be a marked tendency to commit a similar category mistake. Much of the extant literature tends to equate an information system necessarily with the application of digital computing and communications technology. It is evident from a close analysis of signaling games that an information system actually instantiates a different category altogether, and in doing so is best conceived as a meta-concept detached from any particular technologies but which emerges from some 'signaling game'.

Narrating the signaling game

The natural consequence of thinking through the idea of an information system as a signaling game is that that informative artefacts can only be made sense of in terms of the holistic pattern of action making up the signaling game itself. This means that the 'design' of any informative artefact can only be made sense of (Weick 1995) in terms of some repetitive routine of action enacted not only by humans but also by structures within the wider environment such as 'machines' and data structures. As a consequence, to successfully reflect upon and 'narrate' any such 'design' organizational actors cannot focus purely upon the informative artefact itself as a structure, they must focus upon the performativity (D'adderio 2008) of the artefact – what the artefact does within the wider signaling game.

Take an example relevant to digital computing and communication systems. Suppose a health service wishes to design an electronic patient record. Decisions as to what should go on such a record or what should be omitted from such a record can only be taken in terms of the action, or more likely actions, taken with this record. In other words, you cannot design an effective electronic patient record without knowing not only who is likely to use such a record and how, but for what communicative purposes and to initiate what coordinated action.

Three patterns of action

On close analysis it becomes evident that signaling games typically involve three patterns of action, which for lack of better terms we refer to as articulation, communication and coordination. Hence, to make sense of a particular informative artefact and narrate the 'design' of such an artefact to others we need to describe not only the 'structure' of such an artefact, we need to describe how the elements of such structure are articulated by significant actors for the domain in question. Narrators of our signaling game then frequently attempt to relate the particular articulations performed upon the artefact with particular coordinated work actions. But to do this successfully the narrators of any 'design' must deal with the ways in which particular articulations communicate to other actors and how such communication in turn

relates to particular instances of coordinated action. Therefore, a key consequence of the thought experiment of the signaling game is that information is not the same as or different from articulation, communication and coordination. Any proper rendering of information must encompass coupled acts of articulation, communication and coordination.

Take the example of the electronic patient record again. A successful narration of the 'design' of such a record must first describe actions such as how the record is created and by whom. We then need to know something of the 'life-history' of the record – who reads the record; who updates the record and how; and finally, who, if anybody deletes the record and when. But the articulations in themselves are meaningless. To make sense of this artefact, we need to know in terms of each typical event within the 'life-history' of the electronic patient record what the event is meant to communicate. Communication is also not solely about content (reference and predication); it is also about intent (prescription).

For example, an admissions clerk at a general hospital accesses a patient record typically to authenticate the person – to prove that the person is who they say they are. This is typically done by accessing an appropriate identifier for the person (reference) based upon certain details supplied by that person (predication). But in authenticating a person through access to a personal record certain rights are prescribed to this person in relation to the healthcare provision provided by this institution. Being unable to find a particular record on the registry clearly does not mean that the person does not exist. It merely means that the person searched for has not been declared as a patient of the healthcare service. Hence, the end-result of successful access is particularly important in terms of action. The likely result of the access of this record by this organizational actor is that this person will be admitted to the hospital, which will, of course, put in train a whole series of coordinated actions by various different hospital staff, which, in turn, are likely to cause further articulations of this particular artefact…

The coupling of action

The consequence of thinking of a signaling game as an entangled complex of three types of action is that to design any new signaling game we need to narrate the ways in which the three types of action inter-relate or couple. The idea of coupling is taken from the work of Dourish (2004), where he defines it as '*the degree of coordination of two elements, and how that coordination is maintained*'. Coupling can be thought of as narrating the systems of equilibrium within some signaling game, either as is or envisaged. For instance, inherently in our account of the design of the electronic patient record given above we have started to narrate such coupling between domains of action. Hence, a given act of articulation (accessing a particular patient record) undertaken by a particular actor or role (admission clerk) is coupled to a given act of communication (asserts that this is a person entitled to healthcare at this institution), which is coupled in turn to a given act of coordination (admit this patient to the hospital).

The performativity of artefacts

The final consequence of the signaling game is that we must make sense of informative artefacts (such as whiteboards or electronic records) as key actors within such 'games'. This is a key but difficult lesson, even for skilled 'designers' of ways of organizing with informative artefacts. The lesson is that 'machines', such as digital computing systems, and artefacts, like the magnetic whiteboard and its tokens, must be considered as having limited agency within any signaling game (Cooren 2004). This is not only because routine action within modern ways of work is never performed solely by human beings. It is because artefacts such as the whiteboard are essential actors within particular patterns because they help ensure coordinated action (Hutchins, 1995).

In other words, an artefact such as a magnetic token placed upon some whiteboard is not only formed from certain material substance, it serves to inform actors and influence the performance of such actors. For instance, within the signaling game we have described, the whiteboard and the configuration of magnetic tokens deliberately stand in place of a lot of verbal communication between participating human actors. The place of the informative artefact as an actor can be demonstrated quite easily within this context. If we take the whiteboard and its' tokens out of any of the designed patterns, then workers have to develop effective ways of verbally communicating assertions and directions across time-periods. As such, the artefact of the whiteboard must be considered a critical communicative actor in this context.

Information systems are not socio-technical systems

As indicated above, much of the Information Systems literature, either explicitly or implicitly, adopts a view of information systems located upon the IT artefact (Benbasat and Zmud 2003). More recently, Lee *et al* have argued that this is limiting and that the proper artefact to consider in relation to our particular discipline is what they refer to as the information system artefact (Lee, Thomas and Baskerville 2015). For Lee *et al* the information system artefact can be unpacked into a separate 'technology' artefact, 'information' artefact and 'social' artefact. This appears to echo some of the developing consensus surrounding the framing of an information system as a socio-technical artefact or more precisely a socio-technical system.

Adapting a socio-technical view means thinking of an information system as a substantive system made up of the inter-leaving of some system of information technology with some system of work. The suggested relevance of viewing information systems through a socio-technical lens has occurred repeatedly within the discipline of information systems, ever since the landmark paper of Bostrom and Heinen (1977). For instance, the work of Mumford (2006), which has influenced many research studies within IS, explicitly adopts a socio-technical viewpoint. The equally influential body of work by Checkland (1999) implicitly adopts an orienting distinction between soft (human) systems and hard (technical) systems. More recently, Alter's (2003) call for the IS academy to focus on issues relating to IT-enabled work systems clearly employs a socio-technical lens.

But our experience of inquiring into information systems through the thought experiment of a signaling game raises certain doubts about ways in which information systems are conceptualized as socio-technical 'artefacts'. We wish to argue that the conception of an information system as a substantive system consisting of the interaction of two sub-systems (a work system and a technology system) is particularly difficult to apply productively within situation of engagement with information systems in practice. This, we feel, is because a conception of an information system as a socio-technical system fails to adequately account for the emergent nature of information itself as an accomplishment.

Conclusion

Within this paper we have considered a simple thought experiment in which an information system is portrayed as a signaling game. We have used such a thought experiment in a destructive manner to turn the intuition pump in relation to some typical expressions of both the concept of information and the related concept of an information system evident within disciplinary usage. We have also used this game as a constructive thought experiment - as a way of highlighting some of the nature of what information and the associated concept of an information system must constitute.

The original signaling game, as proposed by Lewis, has been applied by Skyrme to demonstrate how communicative conventions do not need to arise spontaneously, nor do they need in some way to be imposed by some external force. Such patterns of equilibrium typically evolve within an action-environment and serve the key purpose of improving 'survival' chances of individual organisms situated within such an environment. We made something of a small intellectual leap in proposing that such patterns help resolve the problematic of information. The consequence of this is that information can be seen to evolve as a collective accomplishment amongst a community of actors. Treating information in this manner also helps us understand how information systems need not be formally designed and imposed upon a community of actors. In many situations the conventions underlying information systems evolve in the complex inter-action between actors and their environment. Therefore, a close analysis of various signaling games as instantiated in examples of both animal and human behavior highlights the multi-faceted nature of information within such systems. We conclude with six central lessons we take from our particular thought experiment.

The thought experiment is not just useful as a way of thinking about how information behavior evolves, it is also useful for thinking about the nature of information itself. The traditional model of information behavior would describe the event of a prairie dog making a bark and another prairie dog making an appropriate flight response as an example of effective information *transfer* from one prairie dog to another (Shannon 1949). But where is the information and how is it transferred between two actors in this situation? Maturana and Varela (1987) argue that nothing is actually transferred between such actors –

there is merely a structural coupling between an actor and its environment. Perturbations in the environment may stimulate changes in the internal environment of a particular actor, which in turn cause it to make changes to its external environment. These changes to the external environment may form perturbations for other actors, and so on…

Information must necessarily be related to materiality (Barad 2007). It is not only related to the idea of material bodies (embodiment) it is related to the idea of such bodies causing perturbations in the physical environment which in turn are used to constitute signals. Such signals are necessarily some pattern of differences (Bateson 1972) encoded in physical stuff. Take the example of the prairie dog signaling the presence of a predator to other prairie dogs. The signal consists of a pattern of sound waves (vibrations in the stuff of air) using two dominant frequencies and divided into short segments of about one tenth of a second in duration. In contrast, a magnetic token is built from more persistent stuff, in which differences present between tokens (such as color) serve to signal appropriate response on the part of human actors.

Information is clearly and closely related to the notion of agency (Rose, Jones *et al* 2005). Agency is typically described as the ability to perform actions that have outcomes. Agency is imbued to agents or actors – some entities that can produce an effect or a change in terms of some environment. But information is normally associated with mutual rather than individual agency. Information is an accomplishment between two or more actors typically directed at what Lewis refers to as coordination problems. A coordination problem arises when people have a purpose or goal in common which must be achieved by joint action. In other words, achieving the goal cannot be achieved by the action of a single individual. Instead, two or more actors must coordinate their actions to achieve the goal. In such situations the effects produced within the environment by the acts of one actor are directed at influencing the actions of another situated actor.

But agency is not limited to humans or other animals. Clearly much action within contemporary institutions is not enacted by humans but by 'machines' and other artefacts such as data structures. This means that the concept of agency is particularly problematic for any discipline such as information systems which attempts to deal with the relationship between technology and institution. In social determinist accounts only humans have agency. In technological determinist accounts technology has agency in the sense that technology influences institutional activity.

Cooren (2004) and others attempt to develop a middle ground where technology, such as the tangible artefacts discussed in our signaling game, not just serve to influence but serve to constitute institutional activity. He makes the key argument that 'texts' such as reports, contracts, memos or work orders can be said to be performing action that have outcomes in the sense of producing effects upon the actions of other actors. In short, 'texts' on their own appear to make a difference to institutions and as such should be considered as having a limited form of agency. To demonstrate this, he uses a thought experiment which has some synergy with the one proposed in the current paper. Imagine a visual sign placed in the reception area of an organization building. This sign acts in the sense of directing people to do certain things such as swiping their entry pass at the entry gate or visiting reception to authorize their entry. As such, the sign stands in place of particular actions typically undertaken by security personnel responsible for controlling organizational entry. The sign acts to instruct people without the need for security personnel to re-iterate the same thing time and again in acts of verbal communication. In a similar manner, the magnetic token of our signaling game serves to stand in place of the assertions and directions of particular human actors in multiple situations where such actors may not be co-present.

Information, at least in terms of its evolutionary course is particularly associated with the idea of embodiment (Varela, Thompson *et al* 1993) – the notion that actors have bodies and both experience and change the world through such embodiment. This means that it is difficult to discuss information without some notion of the sensory and effector apparatus of particular actors. As we have seen, the sensory apparatus of a particular actor denotes the various organs that can be used to sense the external environment. The effector apparatus of a particular actor refers to the various parts of the body that can be used to manipulate or effect the external environment. Both the sensory and effector apparatus of specific actors is related to the notion of a sensory modality. To communicate, one actor must be able to manipulate some aspect of the environment with its effector apparatus; other actors must be able to sense the signal along the sensory modality effected. Various sensory modalities adopted by different species include vision, audition, olfaction and electroreception.

But information, if it is to be associated with the conventions of the human sphere, must rely upon shared intentionality – a collective background of 'aboutness' must exist between observations (sensations), messages (communicative actions) and mutual performance amongst a community of actors. As argued above we do not need to think of information as being transferred between two actors. But we do need some explanatory account of how multiple actors within their internal environment can share goals and action plans. Searle (1983) refers to this ability as collective intentionality and believes it is a capability not only present in humans but also in our closest evolutionary relatives. Tomasello and Carpenter disagree and limit the ability to construct shared intentionality to our own species.

Information is necessarily reliant upon materiality, intentionality, agency and embodiment. Information is objective, subjective, inter-subjective and even a null concept if we try to support the notion of information as the physical transfer of intentions from one actor to another. The tentative conclusion we draw from turning these 'knobs' on our intuition pump is that in essence, information must be an entangled phenomenon. In other words, all four conceptions of information have an inherent truth but only within the context of some signaling game. This means that as an initial proposition it might be best to consider information not as a distinct but as an emergent phenomenon. It emerges from some system of signaling – the complex signaling games that both animals and humans 'play'. As such, the thought experiment of a signaling game offers a way of understanding how specific patterns of communication arise amongst a community of actors and how such patterns adapt to the action – environment important to such actors. The whole point in using the signalling game as a thought experiment to unpack the nature of information was to demonstrate that the sign 'information' is used currently in at least four different ways to denote particular facets of the signalling game itself. My strategy is one of moving the denotation of this sign from the facets of the game individually to the entire system of action that it comprises. This is what I mean by saying that information emerges from such a system of action.

Applying the lens of a signaling game to unpacking particular ways of organizing also offers insight into the proper nature of an information system. A close analysis of thought experiments such as the ones considered in the current paper suggests that the concept of an information system, whether present in situations of animal or human behavior, is best assigned not to the category of substantive systems but to the category of an emergent system. Ryle started an approach to the concept of mind which regards it as an emergent system reliant upon a number of physical systems, most importantly the central nervous system. Likewise, an information system can be observed to emerge from the entangled inter-action of articulation, communication and coordination, all working together. The term information system properly stands for certain properties that emerge from what we have referred to in previous work as the continuous enactment of significance (Beynon-Davies 2011). Such properties emerge from the inter-action between the articulation of material artefacts, the communication of intent that such entails and the coordination of the work of multiple actors that results from such articulation and communication.

References

Alter, S. 2003. "18 reasons why IT-reliant work systems should replace the IT artifact as the core subject matter of the IS field,". *Communications of the Association for Information Systems* (12:23), pp 366-395

Beynon-Davies 2011. *Significance: exploring the nature of information, systems and technology*, Houndmills, Basingstoke, UK: Palgrave/Macmillan.

Beynon-Davies 2013. "Making Faces: Information Does Not Exist,". *Communications of the Association for Information Systems*. (33:19).

Axelrod, R. 2006. *The evolution of cooperation*. New York: Perseus publishing.

Barad, K. 2007. *Meeting the universe halfway: quantum physics and the entanglement of matter and meaning*. Durham, NC: Duke University Press.

Bateson, G. 1972. *Steps to an ecology of mind*. New York: Balantine books.

Beeson, I. 2009. "Information in organizations: rethinking the autopoietic account,". In Maghalez R and Sanchez, R. *Autopoiesis in organization theory and practice*. Bingley, UK: Emerald group publishing.

Benbasat, I., Zmud, R. W. 2003. "The Identity Crisis within the IS Discipline: defining and communicating the discipline's core properties.". *MIS Quarterly* (27:2), pp 183-194

Boland, R. J. 1987. "The In-formation of Information Systems,". *Critical Issues in Information Systems Research*. R. J. Boland and R. A. Hirschheim. New York: John Wiley.

Bostrom, R. P., Heinen J. S. 1977. "MIS Problems and Failures: a socio-technical perspective". *MIS Quarterly* (1:3), pp 17-32
Checkland, P. 1999. *Soft Systems Methodology: a thirty year retrospective*. Chichester: John Wiley.
Cohen, M. 2005. *Wittgenstein's beetle: and other classic thought experiments*. Oxford, UK: Blackwell.
Cooren, F. 2004. "Textual agency: how texts do things in organisational settings,". *Organization* (11:3), pp 373-393
D'adderio, L. 2011. "Artifacts at the centre of routines: performing the material turn in routines theory,". *Journal of institutional economics* (7:2), pp 197-230
Dennett, D. C. 1996. *Kinds of minds: towards an understanding of consciousness*. London: Weidenfield and Nicholson.
Dennett, D. C. 2014. *Intuition pumps and other tools for thinking*. New York: Norton and Co.
Dourish, P. 2004. *Where the action is: the foundations of embodied interaction*. Cambridge, Mass: MIT Press.
Gabriel, Y. and N. A. D. Connell 2010. "Co-creating stories: collaborative experiments in storytelling,". *Management learning* (41:5), pp 507-523
Galsworth, G. D. 1997. *Visual systems: harnessing the power of the visual workplace*. New York: AMACOM.
Gregor, S., Hevner, A. R. 2013. "Positioning and presenting design science research for maximum impact,". *Management Information Systems Quarterly* (37:2), pp 337-355
Grief, M. 1991. *The visual factory: building participation through shared information*. Portland, USA.
Hirano, H. 1995. *5 Pillars of the Visual Workplace: The Sourcebook for 5S Implementation*, Portland, USA: Productivity Press,
Holweg, M. 2007. "The genealogy of lean production,". *Journal of operations management* (25:2), pp 420-437
Hutchins, E. 1995. *Cognition in the wild*. Boston, Mass: MIT press.
Liff, S. and P. A. Posey 2004. *Seeing is believing: how the new art of visual management can boost performance throughout your organization*, New York: AMACOM.
Lee, A. S., Thomas, M., Baskerville, R. 2015. "Going back to basics in design science: from the information technology artifact to the information systems artifact,". *Information Systems Journal* (25:1), pp 5-21
Lederman, R., Johnston, R. B. 2011." Decision support or support for situated choice: lessons for system design from effective manual systems,". *European Journal of Information Systems* (20:5). pp 510-528
Leonardi, P. M., Barley, S. R. 2008. "Materiality and change: challenges to building better theory about technology and organizing,". *Information and Organization* (18:1), pp 159-176
Lewis, D. 2002. *Convention: a philosophical study*. Oxford: Blackwell.
Maturana, H. R., Varela, F. J. 1980. *Autopoiesis and Cognition: the Realization of the Living*, Dordrecht: D. Reidel.
Maturana, H. R. Varela, F. J. 1987. *The Tree of Knowledge: the biological roots of human understanding*. Boston, Mass: Shambhala.
Millikan, R. G. 1984. *Language, thought and other biological categories: new foundations for realism*, Cambridge, Mass: MIT Press.
Mingers, J. 2001. "Embodying information systems: the contribution of phenomenology,". *Information and Organization* (11:2) pp 103-127
Mumford, E. 2006. "The story of socio-technical design: reflections on its successes, failures and potential,". *Information Systems Journal* (16:4), pp 317–342
Rose, J., Jones, M., Truex, D. 2005. "Socio-Theoretic Accounts of IS: the problem of agency,". *Scandinavian Journal of Information Systems* (17:1), pp 133-152
Ryle, G. 1949. *The concept of mind*, London: Hutchinson.
Searle, J. R. 1970. *Speech Acts: An Essay in the Philosophy of Language*, Cambridge: Cambridge University Press.
Searle, J. R. 1983. *Intentionality: an essay in the philosophy of mind*. Cambridge, UK: Cambridge University Press.
Sebeok, T. A. 1972. *Perspectives in Zoosemiotics*, The Hague: Mouton.
Schön, D. A. 1983. *The reflective practitioner: how professionals think in action*, Aldershot: Ashgate.
Shannon, C. E. 1949. *The Mathematical Theory of Communication*, Urbana: University of Illinois Press.
Skyrms, B. 2010. *Signals: evolution, learning and information*, Oxford: Oxford University Press.

Slobodchikoff, C. N., Perla, B. S. , Verdolin, J. L. 2009. *Prairie dogs: communication and community in animal society*, Cambridge, Mass: Harvard University Press.
Statler, M. 2014. "Developing wisdom in a business school? Critical reflections on pedagogical practice,". *Management learning* (45:4), pp 397-417
Stonier, T. 1994. "Information as a basic property of the universe,". *Biosystems* (38:2) pp 135-140
Tomasello, M., M. Carpenter, M. 2007. "Shared intentionality,". *Developmental Science* (10:1) pp 121-125
Tsitchizris, D. C., Lochovsky, F. H. 1982. *Data Models*. Prentice-Hall, Englewood-Cliffs.
Varela, F. J., Thompson, E., Rosch, E. 1993. *The Embodied Mind: cognitive science and human experience*, Cambridge, Mass: MIT Press.