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Article

When Information Conveys Meaning

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Abstract: While some information is clearly meaningful and some clearly is not, no one has been able to identify exactly what the difference is. The major obstacle has been the way information and meaning are conceptualized: the one in the physical realm of tangible, objective entities and the other in the mental world of intangible, subjective ones. This paper introduces an approach that incorporates both of them within a unified framework by defining them in terms of what they do, rather than what they are. Meaningful information is thus conceptualized here as patterns of matter and energy that have a tangible effect on the entities that detect them, either by changing their function, structure or behavior, while patterns of matter and energy that have no such effects are considered meaningless. The way that meaningful information can act as a causal agent in bio-behavioral systems enables us to move beyond dualistic concepts of ourselves as comprised of a material body that obeys the laws of physics and a non-material essence that is too elusive to study [1].

Keywords: meaning; information; cause and effect; observer role; goal-directed behavior; subjectivity; emergence; evolution

1. Introduction

What do we mean when we say that some information is meaningful—and how is it different from information that is not? Although information certainly can convey meaning, it obviously does not always do so. A book written in an unfamiliar language does not convey meaningful information, nor does much of what is stored on the Internet or conveyed by the news media. Some information, like the taste of honey or the cry of a baby, is meaningful to virtually everyone, some, like the shadows on an X-Ray, only to individuals with special training, and some, like noise and nonsense sentences, to no one at all. The distinction between meaningful and meaningless information is, however, not limited to human affairs and language, for it pervades the whole biosphere, from the way that only certain sections of DNA convey usable instructions, to the way that proteins only bind to specific chemicals in their surroundings and fireflies only respond to their species' particular pattern of light flashes—since other ones appear to be meaningless to them

Meaning is an elusive concept that has largely been ignored by the scientists and engineers who study information. Shannon's *Information Theory*, for instance, explicitly excludes it from consideration [2]. While this may not be a problem in dealing with inanimate systems, it has been a major source of confusion in understanding how information operates in bio-behavioral ones, since the ability to detect and respond to meaningful information is key to how cells and organisms regulate their functioning and adapt to their surroundings. What has been lacking is a clear way of distinguishing information that conveys meaning from information that does not. The central issue that has to be addressed is that meaning is not an intrinsic aspect of the arrangements of matter and energy that convey information, but something a human observer attributes to them. It is an inescapably subjective construct that, as far as we know, exists solely in the conscious minds of human beings. It has no objective existence apart from this, is not measurable in any way, and does not obey the ordinary laws of physics. Science has not been able to explain how it occurs or functions, since it does not fit within its current methodologies [3]. This paper offers a new way of thinking about how meaning and information are related, and how they come to cause the effects they produce.

2. Information

The term *information* is used here in the sense initially proposed by Wiener to refer to the way matter and energy are arranged in space and time, a function of the degree to which they are organized in a non-random pattern [4]. Wiener's definition is a theoretical concept that applies to all of the various ways matter and energy are arranged in the universe, independent of whether they can be detected by anyone or have an effect on anything. Information, in this sense, represents a function of the *form* that objects and events exhibit, as distinct from the substances that comprise them. Form is distinct from substance in that it is an intangible, qualitative entity that, like the smile on the Cheshire cat, has no material existence of its own. Form and substance are inseparable aspects of our reality, since you cannot have one without the other. They are, however, independent of each other, so that different types of matter can have the same form, and the same type of matter can have different forms. Thus, although the arrows below contain the same amount of matter, they do not impart the same information, while the adjacent squares convey the same information, even though they consist of different amounts of matter.

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The amount of energy used to convey information is thus unrelated to the amount of information being conveyed, which is why different energy systems can be used to transmit the same information—as long as they are organized and arranged in comparable patterns.

Only a tiny sub-set of the Wiener-type information in the universe is accessible and able to have a material effect, much like the way that only a small fraction of the energy in the universe is available to do work. The reason is that the only way that Weiner-type information can be detected in the natural world is by specialized receptors that exist only in living cells and organisms. Natural selection has shaped the particular types of information detectors with which each cell-type and species is endowed, based on the way they have enabled them to more effectively survive and perpetuate themselves. The types of receptors that cells and organisms possess determine the subset of information they can detect—and shape how they respond to it. Information that cannot be detected or, even if it can, does not have an effect on the detecting entity is thus considered to be meaningless, since only information that makes a difference (*i.e*., causes an effect) conveys meaning [5].

3. Meaning

Meaning is a word that has several meanings, most of which are related to linguistic studies. It is used here, however, in connection with detected information and the effect this has on the entities that detect it. It is, to this end, defined in terms of what it does, rather than what it is, following the pragmatic approach of Peirce and James [6]. The meaning conveyed by detected information is thus determined by the effect it produces in the recipients, either as noted by an external human observer or a self-observing human recipient. It is, in many ways, a construct for explaining why a particular physical or informational cause produced the effect it did. The meaning of a red traffic light, in this way of thinking, is to bring your automobile to a stop, and the meaning of a red strawberry is that it is ripe and ready to eat. Our brain searches for meaning in everything we encounter and we use this knowledge to build systems and models for understanding the world in which we live.

Meaning involves an interpretation of a sensory, emotional or cognitive experience in terms of what it might signify, explain or portend for the particular individual. It is something that a human observer infers about the significance of detected information, based on his or her particular understanding of how the world works—which is why it is always personal [7]. It is not an inherent property of the informational stimulus, but something attributed to it by an observer, so that different individuals can attribute different meanings to the same information, and a given individual can infer varied meanings at different times and in different contexts. Meaning is part of an evaluative process that transforms raw sensory experiences into the workable perceptions that mold our understanding of what is taking place and shapes how we respond to it. We see a red glow in the sky, feel a heavy sensation in our chest, or hear a creak on the staircase, and base our response on what we think these mean. We do not just respond to the information we detect—we respond to how we understand its meaning and significance.

Meaning is an abstract concept that, as far as we can tell, resides solely in the conscious minds of human beings, either in connection with their own experience or what they observe in the behavior of other species. Even though other species detect and respond to meaningful information, they do not appear to reflect on what they experience or understand its significance. Most organisms simply respond to detected information in a fixed and automatic way, with little or no variation between individuals or sense of personal meaning. Fabricated information-processing devices, like *Deep Blue,* the IBM supercomputer that defeated the world chess champion in 1997, also have no sense of the meaning of the information they process; they just respond as they have been programmed to do, without any understanding of what they are doing or why they are doing it.

4. Meaningful Information

Meaningful information represents the subset of Wiener-type information that can be detected and have an effect on the detecting entity. Living entities are equipped with receptors that can detect and respond to certain patterns of matter and energy as the result of either their genetic heritage or individual experience. The ability to detect meaningful information is one of the major distinctions between living and nonliving things, since inanimate objects are unable to do this on their own. Evolution has molded the types of receptors that different species possess, and thus the types of information they can detect, by linking them to responses that facilitate their survival and reproductive success. Even unicellular organisms, like the gut bacterium *E. coli*, have receptors that can detect certain nutrient and toxic substances in their surroundings, which cause them to swim towards the former and tumble away from the latter.

Meaningful information can thus be defined as a pattern of organized matter or energy that is detected by an animate or manufactured receptor, which then triggers a change in the behavior, functioning, or structure of the detecting entity. The detecting entity can be either a macromolecule, a cell, an organism, a plant, an animal, or a fabricated device. If there is no effect on the detecting entity's behavior, functioning or structure, the information is considered to be meaningless as far as the particular individual is concerned at that time [8]. Configurations of organized matter or energy that can be detected and may have an effect but are not currently doing so, such as material stored in computer memories and libraries, are considered here to be *data*. What makes meaningful information so unique, however, is the way that its intangible patterns can cause tangible effects in living cells and organisms.

Meaningful information is thus the means by which one entity can cause a change in the behavior, functioning, or structure of another without a direct exchange of energy or matter between them [9]. Most of the meaningful information in the natural world consists of simple on/off signals that activate pre-programmed responses that have been etched into the various cells and species by evolution and experience. In organisms with a developed central nervous system, the response that information triggers is determined by which receptors are involved, the neural pathways they activate, the associations and memories that are elicited, and the other information they are currently processing. Because the effects caused by the detection of meaningful information are determined by the recipient, rather than the initiating event, they cannot be predicted by the usual laws of physics. The holes in the paper roll of a player piano, for instance, are just signals that activate preprogrammed responses, not the physical cause of the music they generate.

5. Cause and Effect

Meaningful information and free energy are the two primary agents of change in the natural world, the fundamental mechanisms that link cause and effect together. There are, however, a number of critical differences between them. While the energy involved in physical causation is supplied by the originating entity, the energy in informational causation is supplied by the receiving one. This is why cells and organisms (and fabricated information-processing devices) have to have an independent supply of energy, and why entities that do not are unable to detect or respond to information. The effects caused by information also differ from those caused by energy in that they are determined primarily by the recipient's molecular and neural connections, rather than any properties of the stimulus. The response to someone shouting "fire" in a crowded theater, for example, is determined by the meaning the recipients ascribe to the auditory pattern they hear—and is fueled by energy they provide.

Meaningful information that is stored in an individual's genome or memory can also function as an ultimate cause that explains *why* certain living entities function the way they do, separate from the proximate cause that explains *how* they do it [10]. Physics and chemistry look askance at ultimate causes because they do not fit into a mechanistic view of causation. However, the fact that historical causes have no place in the physical sciences is no reason for excluding them from the biologic ones—especially since remote evolutionary and experiential events play a major role in determining how living entities function. While both the animate and inanimate worlds obey the laws of physical causation, living organisms are additionally subject to informational causes that help explain the way they behave—why, for instance, turtles come ashore to lay their eggs, male deer have large antlers, and bowerbirds build elaborate nuptial structures.

Purposive, goal-directed behaviors, like building a nest, flying south for the winter, or investing in the stock market, are one of the hallmarks of animate entities, something that clearly sets them apart from the inanimate ones in nature. The inability of physical explanations to account for such behavior has been a major obstacle to understanding the mind as a part of the natural world—for how can outcomes that have not yet happened cause current events to occur? Because the detection of stored experiential and genetic information can initiate changes that are not explainable on a purely physical basis, non-mechanical causation no longer has to be equated with magic or superstition. Understanding the way that meaningful information can act as a causal agent also provides a way of moving beyond dualistic concepts of ourselves as being comprised of a material body that obeys the laws of physics and a non-material spirit that is too elusive to study. The *vital spirit* that animates living things is not some ethereal force beyond our grasp, but is simply the ability of cells and organisms to detect and respond to meaningful information.

6. The Acquisition of Meaning

Human infants are not born with an ability to ascribe meaning to the information they detect; it is something they gradually learn and acquire. They initially live entirely in the present, without any sense of self or understanding of what is going on around them, like most of the other member of the animal kingdom. Although they can detect and respond to certain information patterns, like the signals that connect them to their caretakers and help regulate their bodily functions, they do so automatically, without any understanding of what these mean. They undergo a miraculous transformation, however, as they become increasingly able to recognize specific objects and individuals, respond differentially to them, and identify relationships that link them together. By the time they are three to four years old, they have acquired a conscious awareness of themselves as unique individuals who can act on the world, reflect on what they experience, and attribute meanings to many of the sensory stimuli that impinge on them. They have, by this time, also begun to express themselves in language and understand the meaning of symbolic information, both of which greatly augment their growing sense of mastery [11].

Meanings are abstractions that express ideas and relationships that do not exist as such in the natural world. They have to be learned and acquired, either from a person's own experience or from information passed on to them by others. There is no guarantee, however, that what a person learns is correct, since each of us develops our own model of the world, based on what we have been exposed to. As a result, the meaning attributed to a given information pattern may vary considerably, especially among people with different backgrounds and belief systems. Even individuals with similar upbringing can infer different meanings and have different responses to the same information as, for instance, when they become superstitious, oppositional, or paranoid. We understand the meaning of the objects and events we encounter by appraising them against the mental models we have previously developed—and misperceive them and respond inappropriately when these fail to portray events accurately.

Learning essentially involves acquiring the ability to detect new patterns of meaningful information (assimilation) and discovering new meanings for patterns that have been previously encountered (accommodation), so that we no longer respond the same way to the same information [12]. In Pavlovian conditioning, for instance, information that was previously meaningless comes to acquire a meaning and trigger a response by being linked to sensory input that is already meaningful to the individual—so that pairing the presentation of meat with the sound of a bell results after a while in the bell alone being able to cause a dog to salivate. Learned information does not even have to be true to trigger a response, which is why confidence artists and demagogues can have such an effect on people, provided they believe that what they are being told is true.

The meaning we ascribe to events may at times say more about us than it does about the events themselves. This is the basis of the Rorschach test, in which subjects are asked to describe what they see when presented with a set of standardized inkblot pictures. Because the way a subject's personality and predilections shape how they interpret these ambiguous stimuli, their responses provide a way of assessing these traits. The distinction between sensation and perception is also evident in the neurological conditions of *agnosia*, in which individuals are unable to perceive what certain sensory stimuli mean. A patient with a visual agnosia, for instance, can copy a drawing of a house or a clock, but cannot tell what they represent, while one with an auditory agnosia can hear the sound made by a siren or a barking dog, but cannot identify what they are. Patients with Alzheimer's disease also lose the ability to tell the meaning of the sensations they detect, so that eventually everything just seems like meaningless noise to them, much as it does to the newborn infant.

7. The Role of the Observer

Meaning is not a property of any of the physical objects in the universe, or of the way they interact or are arranged. It is a mental construct that human observers use to explain how particular patterns of detected information cause the effects they do, either in a cell or organism, or in themselves. Thus, although a foraging bee's 'waggle dance' conveys information about the location of food supplies to its hive mates, it is considered meaningful only by a human observer who notices the effects it causes, not by the bees themselves. Meaning involves a *conscious* appraisal that can only be experienced by individuals who possess our reflective type of consciousness [13].

Our species is unique in the way we search for meaning in the information we detect, and base our response on this, rather than on the sensed information itself. As far as we can tell, the rest of the animate world simply responds to meaningful information without any appreciation of what it actually means. Whether or not the information another entity detects is meaningful to it is thus determined by a human observer, not the entity itself, based on the effect it appears to cause. A frog that detects a small, dark, quick-moving object in its field of vision, for example, responds by turning towards it and striking at its precise location. Although the determination of meaning is based on the frog's actions, it is made by a human observer, not the frog. The observer might explain the frog's behavior by inferring that the "bug-like" information pattern means "something to catch and eat" to the frog [14].

Meaning is by no means the only entity that exists solely in the minds of conscious human beings. There are a great many things in the world that have no material existence of their own and cannot be quantified or explained by lawful principles, like the red color of a rose, the sweet taste of sugar, or the smile on the Mona Lisa. These are all subjective perceptions, conscious appraisals that help us make sense of our sensory experiences. They include abstract concepts, like patriotism and democracy, physical properties, like hot and heavy, values, like good and bad, and moral precepts, like right and wrong. Even though they have no tangible existence, these perceived attributes can cause tangible effects, such as buying a car, getting married, or going to war. As Johnston notes, "The environment is filled with lawful and consistent events, but such happenings are devoid of all meaning, for the laws of physics and chemistry that govern the behavior of these events have no inherent purpose or intention" [15].

8. Science and Subjectivity

Science has evolved as a systematic way of understanding the causal interactions of material objects under both natural and experimental conditions [16]. As science-based knowledge has grown, physical explanations about the universe have gradually replaced magical and animistic ones, since they proved superior at explaining and predicting important events. As a result of this success, mechanistic models of natural phenomena have come to dominate much of today's science, as if they were the only alternative to supernatural beliefs and ideas. This approach has limited science to studying the objective and quantifiable aspects of the universe, an observer-independent realm where meaning and subjectivity are seen as sources of contamination and error, rather than knowledge and understanding [17]. Although information-caused events cannot be deduced from first principles or lawfully predicted the way physically caused ones can, it does not mean that they are inaccessible to systematic study. As with other non-linear forms of causation, it is possible to make statistical predictions about information-caused events that assess the probability of the various outcomes they can generate. Even if everything in the universe is determined (*i.e.*, lawfully caused by its antecedents), it does not necessarily mean it is all determinable (*i.e.*, accessible from known facts and laws).

Subjectively shaped events are, however, not the only ones in which there is no direct, linear connection between cause and effect. The same type of non-linear causality also characterizes the phenomena of *complexity*, where the chain of causality is so involved that it cannot be fully determined, and *emergence*, where the properties of an organized entity cannot be predicted from the properties of its components [18]. The interacting factors that determine the weather, for example, are so complicated that we can only make probabilistic forecasts—and the properties of water so unique that they cannot be predicted from the properties of hydrogen and oxygen. Concepts like emergence, complexity and informational causation thus require a change from the deterministic ways of thinking that believe that brain and behavior will ultimately be understood entirely in terms of physics and chemistry [19].

Science has, however, already given up its deterministic mindset in the sub-atomic realm, but has done this by characterizing it as a strange and unique domain, without realizing that its probabilistic ways of dealing with causation are little different from those used to understand other non-linear phenomena [20]. The scattering of electron paths in quantum theory is not unlike the scattering of views in an opinion poll or the scattering of various types of cancer in a group of 60-year old men. Although we are not able to make *a priori* predictions in these cases, we can make probabilistic ones that are based on previously accumulated data. We can, for instance, predict with a fair degree of accuracy how many people will die of a heart attack or stroke in a given year, based on the incidence of these conditions in prior years. Although we cannot tell which individuals will actually be affected, we can calculate the probability of their succumbing. Most of the events we call accidents or attribute to chance or good luck are also merely ones whose causes are too intricate or obscure for us to fathom, although they can be assessed retroactively—like the way the National Transportation Safety Board investigates aviation accidents. There is nothing strange or mysterious about any of these events, it is just that they are not explainable in the reductionistic paradigm that characterizes much of modern science.

Although most scientists have an aversion to crossing the Rubicon that separates the objective and subjective aspects of the universe, it is a challenge that must eventually be faced if we are to make sense of the role that meaningful information plays in regulating biological and behavioral systems. Science needs to expand its frontiers to include the subjective mechanisms involved in informational causation, both in terms of our own responses and those observed in others. This does not mean it has to embrace the entire array of subjective states, nor does it mean that it has to wholly give up its focus on measurement and quantification, since it only has to include those subjective phenomena that lead to objective, measurable outcomes, like the ones outlined above. Such an integrated approach has, for example, already been utilized successfully in demonstrating how unconscious factors bias human decision-making [21]. The way we process information and determine its meaning can be investigated with the probabilistic approaches that are being used to explore the other forms of non-linear causation. If science is about the pursuit of truth and knowledge, it needs to pursue all the paths that lead there, not just the material and linearly caused ones.

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