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ABSTRACT:
This article provides a comprehensive conceptual analysis of information. It begins with a folk notion that information is a tripartite phenomenon: information is something carried by *signals about* something *for* some use. This suggests that information has three main aspects: structural, referential, and normative. I analyze the individually necessary and jointly sufficient conditions for defining these aspects of information and consider formal theories relating to each aspect as well. The analysis reveals that structural, referential, and normative aspects of information are hierarchically nested and that the normative depends on the referential, which in turn depends on the structural.

KEYWORDS:
information,
conceptual analysis,
paninformationalism

Compared to concepts such as "meaning," "reference," "representation," "value," and "significance," most scientists would prefer the concept of "information." This is because the other concepts are philosopher's playthings, replete with philosophical confusions. Thanks to Claude Shannon, Andrey Kolmogorov, and others, information can be quantitatively defined with mathematical precision and represented in formal theories. Their work was essential for the development of both computer science and communication engineering.[1] Building on these analyses, scientists believe that the concept of information, generally speaking, is more scientifically valid when applied to physics, biology, cognitive science, and social science. Unfortunately, however, confusion and misunderstanding can still arise. Over time, such usage has broadened, and scientific knowledge now goes far beyond the parameters of formal theories. That is, "information" has become confused or conflated with other notions, including message, data, computing, codes, and meaning.[2]

Instead of criticizing the inappropriateness and careless use of these other concepts, I believe that it is necessary to bring their usage into the concept of information because they involve some aspects that are essential to information. However, these aspects are rarely covered by formal theories. Therefore, a crucial task of information studies today is to provide an explanation of information that can help us understand the basic aspects of information and the relationships between them. In order to explain the concept of information, two kinds of work need to be done: conceptual analysis and theory construction. First, the work of conceptual analysis: "In a paradigm case, an analysis embodies a definition; it specifies a set of conditions that are individually necessary and jointly sufficient for the application of the concept. For proponents of traditional conceptual analysis, the analysis of a concept is successful to the extent that the

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proposed definition matches people's intuition about particular cases, including hypothetical cases that figure in crucial thought experiments."[3] Conceptual analysis is necessary for explaining information because while the concept of information is widely used in science, "it is . . . employed somewhat differently in each [physics, biology, cognitive science, and social science], to the extent that the aspects of the concept that are most relevant to each may be almost entirely non-overlapping."[4] This points to the need to articulate the meaning of information both clearly and conceptually, and conceptual analysis can provide us with such an enhanced understanding. Accordingly, the strategy I use in this article includes the following steps: first, I offer an everyday, imagined scenario of information; second, I derive a commonsense notion of information from that scenario; third, I examine the set of conditions that are individually necessary and jointly sufficient for each aspect of information through conceptual analysis; and fourth, I discuss the implications of the formal theories' definitions for each aspect of information.

With conceptual analysis as the starting point, we can then engage with the second kind of work: theory construction. Unlike conceptual analysis, which specifies a set of conditions that define each aspect of information, theory construction is synthetic. It aims to provide explanations about the mechanisms underlying the processes of information. However, to build such theories, more conceptual analysis remains to be done, and thus my attention remains focused on such work.

I argue that information has three unreduced aspects: structural, referential, and normative. I specify the individually necessary and jointly sufficient conditions for defining each aspect via conceptual analysis. As a result, the analysis also shows that those three aspects are hierarchically dependent—that normative information depends on the referential, which depends on the structural. I also argue against paninformationalism, as it claims that information is monistic and everywhere in the cosmos.

In what follows, I first introduce the imagined scenario to illustrate an everyday idea that information is a tripartite phenomenon: information is something carried by a *signal about* something *for* some use. In this conceptualization, information has three aspects—structural, referential, and normative—and in the next three sections, I cover the conceptual analyses of each of these aspects. In addition, I reveal the nested hierarchy of information (i.e., how normative information depends on referential information, which depends on structural information), laying the foundation for future work on information studies. Finally, I address and defend possible objections to the specific claims of each aspect.

INFORMATION AS A TRIPARTITE PHENOMENON

INFORMATION IS COMMONLY UNDERSTOOD AS SOMETHING CARRIED BY *SIGNALS ABOUT* SOMEthing *for* some use.[5] How are we to understand this everyday notion of information? A case provided by Yehoshua Bar-Hillel gives us a good start in illustrating the basic aspects of information captured in common sense:

> *A* writes on a sheet of paper "I love you" and wishes that *B*, 3000 miles away, should become aware of the full content of this message, with little delay and at a low cost. . . . *A* will be dissatisfied if he learns either that his message has been scrambled up, whether into something incomprehensible like "K bogl pou" or into something comprehensible like "a long bow" but with entirely different meaning, or that an undistorted replica has been delivered a day late (and of course, even more so if a distorted message is delivered too late).[6]

The case describes a scenario of communication in which information is transmitted. I call the scenario *A* ♥ (loves) *B*. In *A* ♥ *B*, there is an informer, or source, *A*; there are converters, such as the telegraph machines that encode and recode the message; there is the channel that transmits physical signals encoded by a converter; and there is a receiver, *B*. The whole scenario constitutes a communication system whereby what is transmitted from *A* to *B* is information. In other words, information flows from *A* to *B* through the chosen system of communication. Moreover, communication and information are distinct. Communication is the transmission of information from source to receiver involving both the origin and the end of information. Nevertheless, to understand the concept of information, it is necessary to discuss it in the context of communication.

What the scenario describes is a linguistic communication between two people, *A* and *B*. Human linguistic communication is one of the most sophisticated information processes. Synchronically, information processes in the living world are much richer and more diverse than linguistic communication. Apart from the linguistic form of information processes, there are various extant signaling phenomena, ranging from chemical signals employed by bacteria and plants to the signals that animals employ to communicate. In addition to the information processes at the individual level, there are also others at subpersonal levels, including genetic information, hormones, and so on. For linguistic signaling, the relationship between information and its linguistic carriers is conventional. There is also natural information—for example, smoke carries the information of fire, dark clouds convey the information of pending rain, and tree rings detail the information of the tree's age. Paul Grice was the first to distinguish natural from nonnatural meaning and was followed by Ruth Millikan, who defined information as both intentional and natural signs.[7] Do all of these examples have something in common when treated as being informational? If not, why should we include all of them in a concept of information? What are the differences and connections between linguistic and other forms of information processes? There is no doubt that these are crucial questions of information. However, the conceptual analysis of information is far from being enough to answer these questions. It also requires a comprehensive theory of information. These wider questions are beyond the scope of this article, but because the construction of such theories of information should take conceptual analysis as a premise, its purpose is not irrelevant to the wider goal. In other words, making a blueprint is a prerequisite, a first step, in building a concrete edifice. The conceptual analysis presented here is a blueprint for that theory construction.

Many researchers of theories of evolution believe that the linguistic capacity of *Homo sapiens* evolved from the primary information-processing capacities of primitive organisms.[8] Yet by taking *A* ♥ *B* as an exemplar of information processes, the whole evolutionary history of information is skipped. As a result, some may argue that this article forgoes the possibility of information unification via an unfolding process of increasingly sophisticated information processes. While I agree that the theory construction of information would considerably benefit from illuminating the evolutionary history of information, I believe that beginning with a commonplace scenario is a much easier way to approach a complex phenomenon.

When we say that we collect, store, transmit, and retrieve information, we imply an obvious but widely accepted notion: information is an objective commodity whose generation, transmission, and reception are independent of any preexisting interpretive processes transferred from senders to receivers through channels in communication systems.[9] The message "I love you" that is transmitted from *A* to *B* via the telegraph in the above scenario is the objective commodity represented in symbols. The content of the message and the physical signals in which the message is coded and transmitted are independent of any preexisting interpretive processes.

If we assume that the message is transmitted without distortion, is the message information? Well, it is hard to say. There are several potential scenarios whereby no information is transmitted even though there is a message. First, if *A* actually does not love *B* and is just making a joke, then *B* receives not information but misinformation. I'll return to this concept of misinformation later. Second, if *A* does love *B* but *B* already knows it, then the message is not information, since *B* already knew it, assuming all other things are equal. Third, if the message accidentally is sent to another person, *D*, then the information transmitted is "*A* loves *D*," given that *D* believes the message was for her or him. So from all these scenarios, we can conclude that the *information* transmitted from *A* to *B* is not necessarily identical to the words contained in the message. In these cases, information is confused with the meaning of, or the words representing the meaning of, the message.[10] Then, what is information? The *A* ♥ *B* scenario helps.

In *A* ♥ *B*, *A* will be dissatisfied with three situations:

1. The message is distorted into incomprehensible signals.
2. The message contains comprehensible signals but conveys a different meaning to *B* than was intended by *A*.
3. The message is delivered too late to be useful.

These three situations are hierarchically nested. This means that when a message satisfies its expected purpose (usefulness), it presupposes that the message conveys the correct meaning, which also presupposes that the symbols representing the meaning have not been distorted.

Indeed, situations 1–3 actually correspond to three basic nested aspects of information. These three aspects are *signals*, *aboutness*, and *forness*. The usefulness of information presupposes aboutness, which in turn presupposes certain signals. In turn, usefulness hierarchically depends on aboutness, which hierarchically depends on signals. I'll clarify the hierarchically nested dependence of these three aspects further in the conceptual analysis of each aspect below, but, suffice it to say, this nested situation is consistent with our everyday usages of information. We have a variety of terms to talk about those three aspects: syntactic, semantic, and pragmatic information; measurement, meaning, and usefulness of information; quantity, content, and value of information; and so on.

Claude Shannon can be regarded as the originator of the widely accepted idea that information has three aspects. As he notes, "It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general field."[11] Warren Weaver's classification is also well known. He formulates his classification in terms of communication. If a piece of information is to be transmitted successfully via communication, then three levels of problems must be solved: technical, semantic, and effectiveness. The technical problem concerns the accuracy of the transmission of the symbols of communication; the semantic problem relates to "the identity, or satisfactorily close approximation, in the interpretation of meaning by the receiver, as compared with the intended meaning of the sender"; the effectiveness problem focuses on "the success with which the meaning conveyed to the receiver leads to the desired conduct on his part."[12]

Contemporary researchers also propose conceptual classifications for specific purposes, a practice initially established in the 1950s. To offer a few examples: Marcia Bates's key works classify information into three forms: information 1 (the pattern of organization of matter and energy), information 2 (the pattern with meaning), and knowledge (mental states of a mind as the result of being informed by the pattern with meaning).[13] Luciano Floridi argues that information can be viewed from three perspectives: "information as reality (e.g. as patterns of physical signals, which are neither true nor false). . . ; information about reality (semantic information, alethically qualifiable); and information for reality (instructions, like genetic information, algorithms, orders, or recipes)."[14] Terrence Deacon uses physical, referential, and normative information to refer to these three perspectives, while William Harms argues that there are three crucial concepts of information: statistical, semantic, and physical.[15] Similarly, Niels Gregersen formulates the three as counting, meaning, and shaping information.[16] Even though the above-named researchers use tripartite divisions, this isn't to imply that their divisions map onto each other seamlessly. But there are some obvious similarities—which leads to the question: Do we need yet another attempt to clarify the concept of information?

I argue that existing conceptualizations of information are deficient in some respects, particularly in relation to conceptual analysis. For example, in Bates's and Wolfgang Lenski's formulations, knowledge as a mental state is defined as the result of one's mind being informed.[17] That is to say, knowledge as an informed mental state is a fact. However, as I'll discuss in more detail later, knowledge is deeply involved in the normative aspect of information and, moreover, is not the only result of one being informed; there are also changes in one's actions. Another conceptualization of information is Floridi's insightful classification and his presentation of a map of that covers structural, referential, and normative information.[18] His classification implies a hierarchy of these three aspects, which is also conveyed in the map of information.[19] Floridi's work inspires the research on which this article builds; even so, I believe that yet more comprehensive and explicit analysis is still needed. As I'll also discuss in more detail later, a shortcoming of Harms's aforementioned theory is that statistics are a property of physical (structural) information rather than a parallel to it. Despite such critiques, my analysis benefits greatly from his and others' earlier research findings; indeed, I occasionally cite their insights in this article. The contribution to information studies I make is integrating those previous formulations through the method of conceptual analysis. In doing so, I specify the individually necessary and jointly sufficient conditions for defining structural, referential, and normative information.

Along with these tripartite divisions, in the history of information studies, one of the most enduring framings of the three aspects of information is syntactic, semantic, and pragmatic information. Such terms are borrowed from linguistics, specifically from the work of Charles Morris.[20] His is a language-centric way to frame classification.[21] However, it has several shortcomings. First, these terms are at the center of debates in contemporary philosophy; they are theoretically loaded and thus not a good starting point to begin to understand information. Second, it is widely believed that information is more basic than language.[22] Linguistic symbols are just one among many kinds of signs that convey information. Language is a special derived case of information, not a generic one. Furthermore, applying linguistic glossaries—such as syntax, semantics, and pragmatics—to information studies may confuse linguistic symbols conveying conventional meaning with natural signs carrying natural meaning.[23] It might also obscure critical semiotic distinctions between linguistic symbols and natural signs and overlook a more nuanced continuum. I adopt Deacon's terms—namely, structural, referential, and normative information—to represent these three aspects of information, as his aligns most closely with my formulation. And to better understand those terms, let us now return to the three situations that dissatisfy *A* (1–3 above).

STRUCTURAL INFORMATION

In *A* ♥ *B*, *A* is not satisfied with situation 1, "The message is distorted into incomprehensible signals." This concerns the pattern of symbol sequences or signals carrying information. The pattern of signals can be multiply realized by different physical media. In the case of *A* ♥ *B*, the pattern of "I love you" is realized by the ink written by *A* on the sheet of paper or by electric signals during the pattern's telegraphic transmission. Furthermore, it is difficult to imagine a pattern without a physical manifestation (unless you believe Plato's account that *eidos* is real). In other words, patterns are realized but not determined by the physical, and we call this pattern "structural information."

In order to provide a sufficient definition of structural information, we should first specify its essential elements, check possible relationships between those elements, and then assess what is necessary for the definition. Taken altogether, the elements and relationships between those elements are sufficient for structural information because all necessary elements and relationships have been included. Moreover, conceptual analyses of referential and normative information also follow this approach. In the case of structural information, we can see, *ceteris paribus*, that there are two necessary elements: pattern and its physical realizer(s). As a result, the definition of structural information should seek to answer the following questions: What is a pattern? What is the relationship between a pattern and its physical realizer(s)? Does a pattern identify with its physical realizer(s)? If not, what is a pattern?

With respect to these questions, we call an aspect of information structural information (*Str*) if and only if it has the following properties:

1. It is the pattern or difference manifested by the physical medium.
2. It is realized by the physical, but, nevertheless, the physical is neither sufficient nor necessary for *Str*.
3. It is a concrete abstraction.

Property 1 states that *Str* is the formal aspect of information. In Floridi's term, we can understand *Str* as difference *de re* metaphysically, "i.e., mind-independent, concrete points of lack of uniformity."[24] Floridi defines data as the distinction between two uninterpreted variables.[25] The lack of uniformity, or difference, comes from symmetry breaking.[26] Since *Str* is the lack of uniformity in a physical medium, it is realized by the medium's physical properties.

In our *A* ♥ *B* scenario, *Str* refers to the linguistic symbol sequence, "I love you," Morse code, and electronic signals. All of these are arbitrary products intentionally produced to serve certain functions. However, we should not be misled into thinking that *Str* is limited to arbitrary sign vehicles. Where there is symmetry breaking or a change of state, there is *Str*. Examples of *Str* include agitated states of fundamental particles, a gamma-ray burst of a stellar system far away from the earth, smoke, dark clouds, and so on.

Property 2 states the relationship between *Str* and its physical medium. Informational relationships depend on underlying physical processes but do not identify with them.[27] There is no problem with *Str* being realized by physical properties. For example, the same symbol sequence "I love you" is realized by physical properties, whether they're *A*'s voice, ink on a paper, or electrical signals. Thus, *Str* depends on physical processes. But the sequence is also multiply realized by different physical properties. Thus, *Str* is not identified with physical processes. Furthermore, a physical relationship is neither necessary nor sufficient for an informational relation, which implies that paninformationalism is incorrect.

A physical relationship is not necessary for relaying information. Two events, E_1 and E_2, have a physical relationship when they materially or energetically connect with each other. In terms of *Str*, E_1 and E_2 have an informational relationship when the *Str* of E_1, known as "form" or "pattern," can be detected from E_2. Physical events, of course, can be informative. A gamma-ray burst detected by a Fermi Gamma-ray Space Telescope conveys the *Str* of a stellar system that is billions of light-years away because the burst physically causes the telescope's detection. The ring of a doorbell tells of the arrival of a visitor outside the door because the ring is physically activated by the visitor. However, *Str* is not determined by physical relationships. As I will argue (building on Shannon's theory) in more depth later, the quantity of the generated *Str* of a physical event is not determined by the event itself.[28] That is to say, the quantity of *Str* generated by the event is not determined by the physically present event but by physically absent ones. Some may argue that only when the event physically happens can there be *Str*; thus, a physical relationship is necessary even though the quantity of *Str* is not determined by the physical presence of the event. However, even absent physical events can be informative—for example, "No news is good news!" Or, for instance, imagine a boiler with a reliable alarm. If pressure inside the boiler increases beyond the safety threshold, the alarm will be triggered and signaled via both sound and light. Conversely, if the pressure of the boiler is below the safety threshold, the alarm is not triggered, and the lack of light and sound indicates different information.

A physical relationship is not sufficient for informational relations. Although any causal sequence of physical events can be *Str*, the sequence itself cannot determine which *Str* matters. To return to the example of the doorbell ringing, the ring is the signal that conveys the information of the visitor's arrival. At the same time, the process is a physical causal process: the sound heard by the person inside the dwelling is caused by the vibration of the ring consequent to the electric current, the result of the interaction between two pieces of sheet metal located in the doorbell, which is itself triggered by the visitor pressing the doorbell. Obviously, there are many physical events that happen in the entire process, and the differences or forms realized in any one of them are *Str*s. However, we assume that the ring conveys the *Str* of the visitor's arrival rather than any other *Str*s. This means that a detailed explanation of a causal chain of processes cannot explain which *Str* is conveyed in the chain of events.[29] By implication, then, a physical relationship is not enough to be an informational relationship. I'll return to this argument again in subsequent sections.

Since any difference or constraint is *Str*, *Str* is ubiquitous in the universe. There are scholars who argue that information is *Str* and thus implies paninformationalism or digitalism—that information is monistic and everywhere in the cosmos.[30] I argue that such a view is untenable. This is because, first, if information identifies with *Str*, then we cannot distinguish information from physical events that always have certain structures. Second, information has the property of intentionality—that is, it is about *something*. A signal sequence, a.k.a. *Str*, conveying content is not equal to the conveyed content.[31] Even if a physical event provides *Str*, it tells us nothing about either the referential relationship between the event or its reference and significance. Therefore, information is more than *Str*. *Str* is potentially informational but is not itself information. Further, if information is just form, pattern, difference, organization, structure, and so on, then why must we consider information at all? In this case, the concept of information seems redundant. One reason that we need the concept of information, however, is that it is different from physical events.

If *Str* does not identify with its physical medium, where is its place in the physical world? Property 3 explains what *Str* is. A long-lasting metaphysical question relating to *Str* is, Where is the place of form, or Platonic *eidos*, in the physical world? It appears that forms, patterns, and structures are added to the physical world. We have two ways to answer the question. First, following Plato, *Str* is something abstract but real; it is essentially different from the physical. Second, *Str* is something interpreted by observers. It is not real in the sense of the physical, and it only exists in the observer's mind. Since the first option has long been rejected, the second one seems to be the only choice—that is to say, differences, patterns, forms, structures, organizations, and so on are observer-dependent, not objectively real.[32] However, the second option also leads to a dilemma. On the one hand, it is anti-intuitive to believe that *Str* is as real as, for example, triangles, rectangles, and circles; but on the other hand, if the second option is correct, it has to resolve a more difficult issue: How can the mind produce *Str*? The problem implies a regression: "To attribute physical regularity [a.k.a. *Str*] to some perceived or measured phenomenon presumes a prior mental regularity or habit with respect to which the physical regularity is assessed."[33] Therefore, this option only postpones a solution to the problem; it does not resolve it.

Deacon uses the concept of "constraint" to address the dilemma. Technically, constraint is a term used to describe a reduction in degrees of freedom of change or a restriction on the variation of properties that is less than what is possible. Using constraint to define *Str* in a negative way prevents *Str* from being abstractly general and concretely real. As Deacon notes, "The general logic is as follows: if not all possible states are realized, variety in the ways things can differ is reduced. Difference is the opposite of similarity. So, for a finite constellation of events or objects, any reduction of difference is an increase in similarity. Similarity understood in this negative sense—as simply fewer total differences—can be defined irrespective of any form or model and without even specifying which differences are reduced."[34] In short, constraint of *Str* is the elimination of certain specific features that could have been present. *Str* is abstract in general because constraint reserves the feature that *Str* is the similarity of different particular objects or events. *Str* is real because it is the result of the elimination of particular features that could have been present, the result of certain specific particular processes or events.

Since *Str*s are the results of particular processes, the implication is that *Str*s are measurable. They are measurable in two senses: intrinsically and extrinsically. In the case above, *Str* is the symbol sequence "I love you," which is composed of ten tokens, including eight letters and two blank spaces. Since the aim of the telegraph company is to attract as many customers as possible, the company has a vested interest in providing the service as cheaply as possible. To do that, the company needs to find the most efficient way to encode or describe the sequence, or to measure how much *Str* the message contains in terms of the number of bits required to describe the message. In other words, the complexity of the sequence should be known in order to transmit it most efficiently.[35] The Kolmogorov complexity, an algorithm information theory independently established by Andrey

Kolmogorov, Ray Solomonoff, and Gregory Chaitin, is the way to measure the quantity or the complexity of *Str*.[36] It reveals that the signal sequence determines its own complexity and that we do not need to consider anything other than the sequence itself to measure *Str*. In this sense, we can say *Str* is intrinsically measurable.

This differs from Shannon's extrinsic method of measuring the quantity of *Str*. In his mathematical theory of communication, information is defined as the reduction of uncertainty, and the degree of uncertainty is determined by the number of alternatives that exist.[37] The more alternatives, the more uncertainty. Thus, as alternatives are reduced, more information can be carried by the sent signal—that is to say, the amount of *Str* carried by a signal is determined not by the signal itself but by alternative signals that could have been sent. To illustrate, suppose there are two equally possible states of a source, S_1 and S_2, and two available signals, M_1 and M_2. M_1 represents S_1, and M_2 represents S_2. If S_1 actually occurs, then the quantity of information carried by M_1 is one bit, according to Shannon's formula.[38] If S_1, S_2, M_1, and M_2 are unchanged but there is the possibility of two additional states and two additional signals, then M_1 carries two bits of information rather than one bit. In these two situations, S_1 and M_1 do not change, but the quantity of information generated and transmitted does change. Therefore, the quantity of information measured by Shannon's theory is determined extrinsically rather than intrinsically.

REFERENTIAL INFORMATION

In *A* ♥ *B*, situation 2, "The message contains comprehensible signals but conveys a different meaning to *B* than was intended by *A*," is not satisfactory for *A* because the delivered message's content is different from the original, despite the transmitted *Str* being meaningful and thus comprehensible. The symbol sequence "I love you" as a sentence has the same meaning as the symbol sequence "je t'aime," even though their patterns are different. The referential content of a message, therefore, does not identify with the pattern (i.e., *Str*). In other words, there is no intrinsic relationship between the content of a message and the pattern of the message. *B* will know *A*'s true belief about the love between them through the message and thus reduce uncertainty in *A*'s feeling toward *B*. This is referential information.

In the case of referential information, *ceteris paribus*, there are three necessary elements: the *Str*, the referential relationship, and the object or the event the *Str* refers to. This definition of referential information seeks to answer the following questions: What is a referential relationship? Is a referential relationship determined by a *Str*'s intrinsic properties? Must a *Str* refer to an object(s) or event(s) intrinsically? Or is a referential relationship determined by the referent?

With respect to these questions, we call an aspect of information referential (*Ref*) if and only if it has following properties:

1. It is the relation of a signal (*Str*) to the object it refers to.
2. *Ref* is dependent on *Str* as its vehicle but is not determined by *Str*.
3. It is intrinsically, alethically neutral.

Property 1 states that *Ref* is the aboutness aspect of information—that is, it is the referential relationship between information and the things that the information refers to. Generally speaking, given a referent a signal (*Str*) refers to, when the probability of the occurrence of the signal is different from the probability of the occurrence of the signal per se, then we can say there is a referential association between the signal and the referent.[39] The referential relationship is not intrinsically between the signals and the things the signals are about. For example, the *Ref* carried by the message "Jinping Xi is the president of the People's Republic of China in 2020" has no direct physical relation to the event that "Jinping Xi is the president of the People's Republic of China in 2020." Furthermore, because that same message can be expressed in different languages (symbols) and in different physical forms (e.g., sound, ink, electric screen, etc.), *Ref* is multiply realizable. As a result, *Ref* has no intrinsic relation to *Str*. This is what property 2 claims. Thinking of property 2 in another way, the definition of *Ref* presupposes *Str*; therefore, we can say *Ref* hierarchically depends on *Str*.

Due to their superficial similarities, *Ref* and meaning can be easily confused. But *Ref* is different for a few reasons. First, meaning is a polysemantic concept, as the philosophy of language shows. When we say, for instance, "What is the meaning you want to express?" we are pointing to the semantic content of a sentence. But when we say, "What is the meaning of life?" we refer to the significance or value of life. The connotation of *Ref* is actually much clearer in the first sentence, although not entirely free from confusion. Second, while semantic content may be similar to *Ref*, the former is a linguistic-centered concept, whereas the latter is more fundamental and is not limited to linguistic phenomena, as argued above. Third, the *Ref* conveyed by a symbol may not concur with its conventional meaning.[40] On the one hand, the *Ref* conveyed by a sign may exceed the conventional meaning of the sign. For example, when I see a sentence on a paper, I might not understand the original source's information until I read the sentence in its original context and remember it. As Fred Dretske explains, "The information carried by that signal depends in part on what one already knows about the alternative possibilities."[41] This echoes what Shannon tells us in his theory of information.[42] On the other hand, natural signs like footprints of animals on the ground, a tree's growth rings, dark clouds, someone's facial expression, and so on, have no conventional meanings, yet they surely carry *Ref*. Symbols that have meaning, furthermore, may not convey any *Ref* at all: in *A* ♥ *B*, the message "I love you" sent by *A* to *B* is information for *B* only when *B* does not know that *A* loves *B*. If *B* already knows that *A* loves *B*, then the message is redundant and not informational for *B*, even though the meaning did not change. Moreover, if I say to my wife that "I am busy writing my book" when I am actually playing a game on my mobile phone, then the words convey no information to my wife because I am not telling the truth. In other words, the meaning represented by my words does not correctly correspond to the facts. The scenario implies that *Ref* must be necessarily true. This is the so-called veridicality thesis.

While I agree with the veridicality thesis, misrepresentation is not unusual. A spy can deceive an enemy by intentionally spreading false information (disinformation); an unaware guard can mistake a stranger for an employee (misinformation).[43] Intuitively, we do not think any information has been conveyed in these two situations. Why is this the case? According to a formulation of Shannon's communication theory, information is the reduction of one's uncertainty about a subject by eliminating alternative possibilities.[44] False information cannot eliminate alternative possibilities and reduce one's uncertainty. Suppose *B* loves *A* but did not know whether *A* loves *B* before the scenario took place. In other words, *B* is uncertain about *A*'s feelings. After receiving *A*'s message, *B*'s uncertainty is reduced on the condition that the message corresponds to the fact that *A* loves *B*. If *A*, in fact, does not love *B* and sends the message to manipulate *B*'s feelings, then *B* may believe uncertainty has been reduced, but in actuality, *B* has been misled. In this scenario, the message is disinformation. In fact, to emphasize the misleading nature of disinformation, Don Fallis renames it "misleading information."[45] By extension, veridicality is an intrinsic property of information, and thus neither misinformation nor disinformation is a kind of information.[46] If this is so, why do we still call them *mis*information and *dis*information? Dretske argues that "this is a pretty heavy-handed treatment of ordinary language."[47] Put another way, misinformation and disinformation are not information—just like decoy ducks are not real ducks.

Superficially, the discussion of the veridicality thesis is inconsistent with property 3, which asserts that *Ref* is intrinsically, alethically neutral. Actually, veridicality is not. It is a property of information but not of *Ref*. What *Ref* characterizes instead is just the referential association between signals (*Str*s) and their referents. However, *Ref* cannot determine the relation itself, because everything associates with everything in one way or another. Think of the doorbell scenario mentioned in the previous section. The sound of the doorbell can be tied to any event in the causal chain. Therefore, to discuss the truth value of *Ref* by itself is empty. The doorbell conveys the information of the visitor's arrival because the designer intended it to do so. The problem of referent determination of a signal, then, is about the normative aspect of information. I discuss this further in the next section.

Many scholars believe that *Ref* is measurable, and they set out to construct ways of defining the quantity of *Ref*.[48] Other scholars disagree with this interpretation. For example, as Dretske argues, given that a receiver already knows about the possibility of the source, only when the conditional possibility of event *s* being event *F* is 1 can we say that a signal carries the information *s* is *F*.[49] If the sent and the received messages are different, even slightly, then qualitatively they are two different messages. However, this interpretation does not hold for all possibilities, because it is counterintuitive.[50] For example, intuitively, the message "Luciano Floridi is a male Italian philosopher of information" carries more *Ref* than the message "Luciano Floridi is a philosopher." But in what sense? According to Bar-Hillel and Rudolf Carnap, it is because the possibility of the former occurring is less than that of the latter.[51] Their formulation, though, leads to a paradox that an analytic proposition carries no *Ref* and a proposition of contradiction carries infinite *Ref*.[52] Floridi might then argue that the degree of truth brought about by the first message is greater than the second message.[53] Brian Skyrms, on the other hand, would claim that the first message has more *Ref* than the second because the first has more vectors.[54] This article's argument, in contrast, is a pluralist position regarding how to characterize the quantity of *Ref*. So long as a theory of the measurement of *Ref* fulfills its designed purpose, then it is acceptable. Nevertheless, what remains unclear is the claim that *Ref*'s measurability conflicts with Dretske's assertion. That two messages with minor differences are qualitatively two different messages does not mean that they are quantitatively incomparable. So long as one provides an acceptable standard of understanding, then they are comparably measurable. Qualitative differences matter in normative information. This will be examined in the next section.

NORMATIVE INFORMATION

In *A* ♥ *B*, *A* is not satisfied with situation 3, "The message is delivered too late to be useful," because his purpose is unfulfilled by the delayed message. It cannot make the difference he wants, in Gregory Bateson's terms.[55] Suppose *B* is getting engaged to another person the next day. Despite the fact that *B* loves *A*, *B* cannot wait any longer, because *B* does not know *A*'s mind, and *B*'s family is pressing for a decision. So *A* has to let *B* know *A*'s feelings before *B*'s engagement, or nothing can be resolved. It follows, then, that information is time-sensitive, even though the delivery of words and their content do not change. More generally, information is contextually sensitive. For example, the delivered message has a different value for *A* compared to the value for the telegrapher who sends it. *A* can use the symbol sequence "I love you" to express a thought to *B* because the symbol sequence holds the same meaning for both *A* and *B*. Put differently, the symbol sequence "I love you" is supposed to function as one person's expression of love to another in a two-person communication. The same is the case with *Ref*; that is, *A* cares less about how the message is symbolically (*Str*) delivered and more about if the message was delivered correctly and on time. We call this aspect of information "normative information."

With normative information, *ceteris paribus*, its necessary elements are *Ref* carried by *Str*, the effect caused by *Ref*, and the value for the user of the information. Then, the definition of normative information should answer the following questions: Why is a signal dedicated to a certain referent? What is the relationship between *Ref* and the effect it causes? What is the relationship between *Ref*, the effect *Ref* causes, and the value for information users?

With respect to these questions, we can call an aspect of information normative (*Nor*) if and only if it has following properties:

1. It is stabilized as being useful for information users.
2. It depends on but is not determined by *Ref*; in turn, it determines the specific referential association between a *Str* and its referents and thus determines *Ref* of the *Str*.
3. It is sensitive to contextual factors.

Nor is concerned with information's usefulness aspect. An intuitive description of *Nor* is that it is a difference-maker.[56] As Bateson correctly claims, *Nor* is "a difference which makes a difference."[57] Here, Bateson is taking advantage of the ambiguity between two meanings of "make a difference," that is, "to matter" and "to cause to change."[58] *Nor* is always used for some end and is thus related intrinsically to usefulness. Only when a message changes the epistemic or action state of a receiver can we refer to it as *Nor*. For example, the message "a whale is a mammal" would be new information to people who lived in China two thousand years ago, but it is not (new) information for most people today because it is well-known and has lost its novelty; that is, the information does not change these people's epistemic state. Instead, it leads to property 2. The value of information, a.k.a. *Nor*, is contextually sensitive with respect to time, individual receivers, and other factors. For example, "Terrence Deacon is a faculty member in the Department of Anthropology at the University of California, Berkeley" is not *Nor* for me, but it is for my mother. This is what property 3 asserts. I will return to this point momentarily.

Property 1 states not only that *Nor* is useful but also that it is stabilized as being useful. Millikan calls this the proper function, or the stabilizing function, of a message (*Str* + *Ref*): the same information supposedly always reliably serves a specific function.[59] For example, in *A* ♥ *B*, the message "I love you" is always supposed to function as one person's expression of love to another person. This makes possible interpersonal communication. But how can a message stabilize and reliably realize a certain function? After all, a user of information could employ (interpret) a physical token as a *Str* being about anything, since, theoretically speaking, anything can be associated with anything in one way or another.

However, the relationship between physical tokens, or any *Ref*, and *Str* is not arbitrary. Only those *Ref*s that contributed to a function in the past are stabilized as the *Nor* of *Str*s.[60] As a result, the *Ref* of a *Str* is determined in the stabilizing process. Furthermore, the emergence of *Nor* in the *Ref-Str* stabilizing process takes the existence of *Ref* and *Str* as its premise. It is the stabilized relationships between *Ref* and *Str*s and the resulting effects that define *Nor*. This is what property 2 claims. What also becomes evident is that *Nor* presupposes *Ref*, which presupposes *Str*. Thus, *Nor* hierarchically depends on *Ref*, which hierarchically depends on *Str*.

Additionally, *Nor* is concerned with the effects of information, implying that information has causal power. As a difference-maker, *Nor*'s causal power is not derived from its physical realization. Norbert Wiener claims, in a chapter of his magnum opus, *Cybernetics: Or Control and Communication in the Animal and the Machine*, that "information is information, not matter or energy."[61] He recognizes that any mechanism that processes information must use a certain amount of energy, no matter whether it is a computer or a brain.[62] The physical consequences caused by information, however, cannot be explained by energy cost. For example, an order given by a captain to launch an attack might cost the captain very little energy, but the order may have much greater consequences that are unexplained by the energy cost of the order. Therefore, there is no intrinsic relationship between *Nor* and its physical embodiment.

How can we understand the contextual sensitivity of *Nor* regarding the proper function of a message as stabilizing and reliable? I argue that a crucial answer to this question can be found in the confusion between two different levels of *Nor*. Returning to the properties of *Nor* mentioned earlier, *Nor* can be understood as either a type or a token under different conditions: property 1 and property 3 occur at different levels. When *Nor* is in property 1, it refers to its proper function and, thus, is a type. In actual contexts, *Nor* is a token in property 3 when realizing its proper function (Nor_1). *Nor* can be seen as a token in two senses: first, as an individual's intention for a message (Nor_2), and second, as the actually realized consequences once the message is delivered and the receiver takes action accordingly (Nor_3). Taking *A* ♥ *B* as an example, the Nor_2 of the message for *A* is to let *B* know that *A* loves *B*. If the message is delivered successfully with no distortion, and *B* was unaware that *A* loved *B* prior to receiving the message, then Nor_3 is *B* gaining new knowledge that *A* loves *B*. In this case, Nor_1, Nor_2, and Nor_3 are consistent. But there are cases in which these three are inconsistent. For instance, if *A* actually does not love *B* but intends to play with *B*'s feelings, then the Nor_2 of the message mismatches the Nor_1. If the telegrapher at the decoding end wrongly decodes the message into, say, a German one, "ich liebe dich," and *B* doesn't know German, then the Nor_3 for *B* will be a meaningless symbol sequence. Nor_3 in this case is inconsistent with Nor_1 and Nor_2.

But if *Nor* is understood at these two different levels, some questions still remain: How do Nor_1, Nor_2, and Nor_3 relate to one another? How does Nor_1 as a type emerge? Does it emerge from Nor_2 and Nor_3, as a type from tokens? If so, then how are Nor_2 and Nor_3 realized in relation to Nor_1? As tokens of a type? These questions reveal an underlying metaphysical question: Can nonphysical entities have physical consequences?

Altogether, these questions intimately connect with the theorem of double contingency in communication first proposed by Talcott Parsons and further investigated by Niklas Luhmann.[63] The theorem proposes a conceptual possibility that miscommunication happens in social interactions. Suppose two human agents, Amy and Billy, interact with each other through a set of signals. As a part of the communication, Amy has to choose a signal that properly represents her idea and that successfully achieves her intention. Billy, as the other agent in the interaction, has the freedom to understand Amy's signal in any way he chooses. The double contingency in the example refers to the freedom both agents have to select their own alternative interpretations. That is to say, how Amy and Billy understand the signal is contingent. It is possible that their understandings might be different. As a result, miscommunication can occur. More often than not, though, communication in social life is successful, while miscommunication is rarer. Why is this the case?

If we illustrate the theorem of double contingency through *Nor*, the answer becomes clear. Amy and Billy individually understand the signal to be their own Nor_2s. Consequently, one person's Nor_2 is the other person's Nor_3, and vice versa. In the case of miscommunication, Amy's Nor_1 and Billy's Nor_1 differ, and, as a result, Nor_1 is inconsistent with Nor_3 for each. Communication is typically successful, while miscommunication is rare, because a signal has Nor_1. Amy's Nor_2 and Nor_3 and Billy's Nor_2 and Nor_3 are consistent with Nor_1. Thus, the problem of communication is translated to the questions mentioned above. However, answering those questions is the project of theory construction rather than of conceptual analysis.

A survey of the literature reveals that discussions have primarily centered on measuring the *quantity* of *Str* and *Ref*, with relatively few examinations of the measurability of *Nor*. Mark Burgin's work is an exception. He reviews three kinds of theories of *Nor*: economic, mission-oriented, and transformational.[64] In those theories, the way to think of *Nor* is to consider the value of information in decision-making and action. *Nor* is determined by its contribution to one's decision-making and the outcome of the action taken according to that decision. *Nor* can be measured by changes in the probability distributions of one's expectations and of the effects of actions with respect to the intended outcome.[65] There are correspondences between the theories Burgin reviews and the terms I employ in this article: changes of expectation correspond to Nor_2, the actual effects of actions to Nor_3, and the stabilizing probability distribution of those two to Nor_1.

Moreover, it is necessary to note that Nor_1 is not the average of Nor_2s and Nor_3s, as Millikan has emphasized.[66] And the theories Burgin reviews are also about the average of Nor_2 and Nor_3. All of this implies that we still need a formal theory of Nor_3. Signaling games theory, first proposed by David Lewis and further developed by Skyrms, may offer a solution.[67] Signaling games theory aims to explain how the meaning (*Nor*) of signals spontaneously emerges and evolves in social interactions between senders and receivers. Another approach to formally characterize *Nor* that has been recently rediscovered by researchers is Charles Sanders Peirce's theory.[68] Peirce uses logical quantities to measure *Nor*, which differs from those theories that formally characterize information through calculus of probability. Peirce's theory measures information contributing to knowledge growth by assessing changes in breadth and depth of knowledge. I contend that, despite Peirce's methods, his theory is not inconsistent with those theories discussed above—if we understand knowledge to be justified true beliefs, which are the mental states of being informed.

Conceptual analysis of the structural (*Str*), referential (*Ref*), and normative (*Nor*) aspects of information reveals that these three aspects are not just different characterizations from different perspectives. The analysis also reveals the hierarchical, nested nature of these three aspects and how they are asymmetrically dependent on one another. *Nor* depends on *Ref*, which depends on *Str*. Thus, an analysis of *Str* can provisionally ignore the consideration of *Ref* and *Nor*, an analysis of *Ref* requires consideration of *Str* but can provisionally ignore the consideration of *Nor*, while an analysis of *Nor* requires consideration of both *Ref* and *Str*. The analysis of the hierarchy of *Str*, *Ref*, and *Nor* done here has been in the spirit of Bates's and Deacon's work, with one important difference. I incorporate Floridi's argument that, because of the hierarchical nature of information, the concept of information can be used in different domains at proper levels of abstraction.[69]

CONCLUSION

INFORMATION IS SOMETHING CARRIED BY *SIGNALS ABOUT* SOMETHING *FOR* SOME USE. THEORISTS abandoned the aboutness and usefulness of information for engineering purposes in early mathematical theories. Nevertheless, the concept of information used in many fields still unavoidably involves those aspects, which has led to much confusion. Information becomes conflated with many other concepts, such as message, data, computing, codes, and meaning. In order to understand information, two kinds of work are necessary: conceptual analysis and theory construction. Theory construction should take conceptual analysis as a premise because the latter provides a map upon which problems of information are explicitly marked; this article has offered just such a conceptual analysis of information.

Although many disagree on what information is, there is some consensus that information is a tripartite phenomenon. I adopt Terrence Deacon's terms to refer to those three aspects of information: structural, referential, and normative. Structural information originates from symmetry breaking: where there is difference, there is structural information. Structural information is also objective and thus can be measured intrinsically and extrinsically. Referential information concerns the referential relationship between signal and source. It should not be confused with meaning, which occupies a central place in the philosophy of language. Referential information is much more basic than meaning and not limited to linguistic phenomena: it mismatches with meaning and is alethically neutral. The normative aspect is the usefulness, or function, of information. It can be understood on two levels: type and token. A signal normally has stabilized functions, which may differ from intentional function and actually realized function. Structural, referential, and normative information are hierarchically nested, so that the normative depends on the referential, which depends on the structural.

With conceptual analysis, it is possible to construct a theory of information. I believe that a theory of information should explain structural, referential, and normative information. However, the most widely known theories, such as Shannon's mathematical theory of information and algorithm theory of information, as I have argued, are concerned only with the measurement of the quantity of structural information. Over time, however, referential and normative aspects have been lost in many formal theories. Therefore, a task of information studies today is to restore these aspects to the understanding of the concept of information.

NOTES

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1. See Andrey N. Kolmogorov, "On Tables of Random Numbers," *Sankhya: The Indian Journal of Statistics*, Series A, 25, no. 4 (1963): 369–76; Kolmogorov, "Three Approaches to the Quantitative Definition of Information," *International Journal of Computer Mathematics* 2, no. 1–4 (1968): 157–68, https://doi.org/10.1080/00207166808803030; Claude E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal* 27, no. 3 (1948): 379–423, https://doi.org/10.1002/j.1538-7305.1948.tb01338.x.
2. For a helpful description of this chaotic situation, see Rafael Capurro and Birger Hjørland, "The Concept of Information," *Annual Review of Information Science and Technology* 37, no. 1 (2005): 343–411, https://doi.org/10.1002/aris.1440370109. For a more recent and personal summary, see Joseph E. Brenner, "Information: A Personal Synthesis," *Information* 5, no. 1 (2014): 134–70, https://doi.org/10.3390/info5010134.
3. Eric Margolis and Stephen Laurence, "Concepts," in *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, https://plato.stanford.edu/archives/sum2019/entries/concepts; Don Fallis, "What Is Disinformation?," *Library Trends* 63, no. 3 (2015): 401–26, https://doi.org/10.1353/lib.2015.0014.
4. Terrence Deacon, "Shannon-Boltzmann-Darwin: Redefining Information. Part 1," *Cognitive Semiotics*, no. 2 (2007): 123–48.
5. By no means will everyone agree with the seemingly commonsense idea that information is a tripartite phenomenon. Many people, especially those in the sciences, intuitively adopt Shannon's view of information. One motivation behind pursuing a unified theory of information, if understood correctly, is to go beyond Shannon's mathematical theory of communication. Other people may believe that information has something to do with people. The commonsense example used in this article is based on the imagined daily scenario taken from Yehoshua Bar-Hillel, "An Examination of Information Theory," *Philosophy of Science* 22, no. 2 (1955): 86–105. Instead of uncritically taking the scenario as the basis for the conceptual analysis of information, I use it as a starting point to specify the set of conditions that can define each aspect of information.
6. Bar-Hillel, 86.
7. H. Paul Grice, "Meaning," *Philosophical Review* 66, no. 3 (1957): 377–88, http://www.jstor.org/stable/2182440?origin=JSTOR-pdf; Ruth Garrett Millikan, *Varieties of Meaning: The 2002 Jean Nicod Lectures* (Cambridge, MA: MIT Press, 2004).
8. See, for example, Terrence W. Deacon, *The Symbolic Species: The Co-evolution of Language and the Brain* (New York: W. W. Norton & Company, 1997).
9. Fred I. Dretske, *Knowledge and the Flow of Information* (Cambridge, MA: MIT Press, 1981), vii.
10. The confusion beween information and words will be articulated in the "Structural Information" section, and the confusion between meaning and information will be cleared up in the "Referential Information" section.
11. Claude Elwood Shannon, *Collected Papers*, ed. N. J. A. Sloane and Aaron D. Wyner (New York: IEEE Press, 1993), 130.
12. Claude E. Shannon and Warren Weaver, *The Mathematical Theory of Communication* (Urbana: University of Illinois Press, 1964), 4, 5.
13. Marcia J. Bates, "Information and Knowledge: An Evolutionary Framework for Information Science," *Information Research: An International Electronic Journal* 10, no. 4 (2005), http://www.informationr.net/ir/10-4/paper239.html; Bates, "Fundamental Forms of Information," *Journal of the American Society for Information Science and Technology* 57, no. 8 (2006): 1033–45, https://doi.org/10.1002/asi.20369.

14. Luciano Floridi, *The Philosophy of Information* (Oxford: Oxford University Press, 2011), 30.
15. Terrence Deacon, "Steps to a Theory of Reference & Significance in Information," FIS discussion paper, September 2015, http://listas.unizar.es/pipermail/fis/2015-January/000174.html. Recently, Deacon has revised the term "physical information" to "structural information" (personal communication, September 9, 2020); William F. Harms, "What Is Information? Three Concepts," *Biological Theory* 1, no. 3 (2006): 230–42, https://doi.org/10.1162/biot.2006.1.3.230.
16. Niels Henrik Gregersen, "God, Matter, and Information: Towards a Stoicizing Logos Christology," in *Information and the Nature of Reality: From Physics to Metaphysics*, ed. Paul Davies and Niels Henrik Gregersen (Cambridge: Cambridge University Press, 2010), 319–48, https://doi.org/10.1017/CBO9781107589056.019.
17. Bates, "Fundamental Forms," 1033–45; Wolfgang Lenski, "Information: A Conceptual Investigation," *Information* 1, no. 2 (2010): 74–118, https://doi.org/10.3390/info1020074.
18. See, for example, Jens-Erik Mai, "The Quality and Qualities of Information," *Journal of the American Society of Information Science and Technology* 64, no. 4 (2013): 678–88, https://doi.org/10.1002/asi.22783.
19. Luciano Floridi, *Information: A Very Short Introduction* (Oxford: Oxford University Press, 2010), 18.
20. Roland Posner, "Charles Morris and the Behavioral Foundations of Semiotics," in *Classics of Semiotics*, ed. Martin Krampen (New York: Plemun Press, 1987), 25.
21. Deacon, personal communication, September 29, 2015.
22. For example, see Dretske, *Knowledge*, vii; Floridi, *Philosophy of Information*, 81; Terrence W. Deacon, *Incomplete Nature: How Mind Emerged from Matter* (New York: W. W. Norton & Company, 2012), 372.
23. Grice, "Meaning," 378; Millikan, *Varieties*, 31–45.
24. Floridi, *Information*, 356.
25. Floridi, 17.
26. John Collier, "Information Originates in Symmetry Breaking," *Symmetry: Culture & Science* 7, no. 3 (1996): 247–56.
27. Dretske has argued that causal relations are neither necessary nor sufficient conditions for informational relations (see *Knowledge*, 156–68). I agree with his argument that detailed descriptions of the causal process upon which an informational relationship depends cannot reveal what the information is. However, I do not think his argument that a causal relationship is unnecessary for an informational relationship is successful, since his interpretation of causality is dubious. Dretske defines a causal relationship as a regular, law-like succession between two events. He uses two cases to argue that the relationship is an informational relation but not causal. One case is that an event may indeterminately cause three other different, equally probable events. The other case is that an event may cause two events. Although there is no causal relation between the caused events, any of the two can inform the other. These two cases are not causal relations, according to Dretske's definition. His definition is too rigid to include periphery cases of causation. According to some recent works on causation, there are no problems in including the two cases as causal relations (e.g., see the entry by Christopher Hitchcock, "Probabilistic Causation," in *The Stanford Encyclopedia of Philosophy*, Spring 2021, ed. Edward N. Zalta, https://plato.stanford.edu/archives/spr2021/entries/causation-probabilistic/). In order to avoid unnecessary debates, I use the weaker concept, "physical relation," rather than "causal relation."
28. Shannon, "A Mathematical Theory," 32–33.
29. The difficulty referred to here is called the content-determinacy challenge, and it is raised by Jerry A. Fodor, *A Theory of Content and Other Essays* (Cambridge, MA: MIT Press, 1990),

who argues against the teleosemantic program. It is also mentioned by Dretske himself (see *Knowledge*, 26–39). A detailed formulation of this difficulty can be found in Karen Neander, *A Mark of the Mental: In Defense of Informational Teleosemantics* (Cambridge, MA: MIT Press, 2017), 149–74.

30. Examples include Konrad Zuse, "Rechnender Raum," *Elektronische Datenverarbeitung* 8 (1967): 336–44; John Archibald Wheeler, "Information, Physics, Quantum: The Search for Links," in *Complexity, Entropy, and the Physics of Information*, ed. Wojciech H. Zurek (Redwood City, CA: Addison-Wesley, 1989), 354–58; Tom Stonier, *Information and Meaning: An Evolutionary Perspective* (Berlin: Springer, 1997), 1; Juergen Schmidhuber, "A Computer Scientist's View of Life, the Universe, and Everything," in *Foundations of Computer Science: Potential-Theory-Cognition*, ed. Christian Freksa, Matthias Jantzen, and Rüdiger Valk (Berlin: Springer, 1997), 201–8; Stephen Wolfram, *A New Kind of Science* (Champaign, IL: Wolfram Media, Inc., 2002); Gordana Dodig-Crnkovic, "Dynamics of Information as Natural Computation," *Information* 2, no. 3 (2011): 460–77.

31. Yehoshua Bar-Hillel and Rudolf Carnap, "Semantic Information," *British Journal for the Philosophy of Science* 4, no. 14 (1953): 147–57, https://doi.org/10.1093/bjps/IV.14.147; Bar-Hillel, "An Examination."

32. Deacon, *Incomplete Nature*, 187–89.

33. Deacon, 189.

34. Deacon, 190.

35. Ming Li and Paul Vitányi, *An Introduction to Kolmogorov Complexity and Its Applications*, 3rd ed. (New York: Springer, 2008), 101.

36. Kolmogorov, "On Tables"; Kolmogorov, "Three Approaches"; R. J. Solomonoff, "A Formal Theory of Inductive Inference, Part I," *Information and Control* 7, no. 1 (1964): 1–22, https://doi.org/10.1016/S0019-9958(64)90223-2; Solomonoff, "A Formal Theory of Inductive Inference, Part II," *Information and Control* 7, no. 2 (1964): 224–54, https://doi.org/10.1016/S0019-9958(64)90131-7; Gregory J. Chaitin, *Algorithmic Information Theory* (New York: Cambridge University Press, 1987).

37. Shannon, "A Mathematical Theory," 32–33.

38. Shannon, 32–33.

39. Nicholas Shea, *Representation in Cognitive Science* (Oxford: Oxford University Press, 2018), 76.

40. The argument below comes from Dretske, *Knowledge*, 41–47. However, I disagree with him that "the information embodied in a signal (linguistic or otherwise) is only incidentally related to the meaning (if any) of that signal" (44). I believe the relation between the information and the meaning of a sign is not just incidental.

41. Dretske, 43.

42. Shannon, "A Mathematical Theory," 32–33.

43. Generally, the discussions of disinformation and misinformation are concerned with action. See Christopher John Fox, *Information and Misinformation: An Investigation of the Notions of Information, Misinformation, Informing, and Misinforming* (New York: Greenwood Press, 1983); Fallis, "What Is Disinformation?"

44. Charles R. Berger and Richard J. Calabrese, "Some Exploration in Initial Interaction and Beyond: Toward a Developmental Theory of Interpersonal Communication," *Human Communication Research* 1, no. 2 (1975): 99–112, https://doi.org/10.1111/j.1468-2958.1975.tb00258.x.

45. Fallis, "What Is Disinformation?" 401–2.

46. Floridi gives two arguments on the veridicality thesis. The first is that the use of "false" in "false information" is attributive (there will be semantic loss if we split "false" from the whole phrase), while the use of "true" in "true information" is predictive (without it, there is no semantic loss). Floridi's second argument is a semantic one verifying that ordinary phenomena of semantic erosion will be hard to understand. For more, see Floridi, *Philosophy of Information*, 80–107.

47. Fred Dretske, "The Metaphysics of Information," in *Wittgenstein and the Philosophy of Information: Proceedings of the 30th International Ludwig Wittgenstein Symposium, 2007*, ed. Alois Pichler and Herbert Hrachovec (Berlin: De Gruyter, 2008), 273–84, https://doi.org/10.1515/9783110328462.

48. See, for example, Yehoshua Bar-Hillel and Rudolf Carnap, "An Outline of a Theory of Semantic Information," reprinted in *Language and Information: Selected Essays on Their Theory and Application*, by Yehoshua Bar-Hillel (1953; repr., Reading, MA: Addison-Wesley, 1964), 221–74; Luciano Floridi, "Outline of a Theory of Strongly Semantic Information," *Minds and Machines* 14, no. 2 (2004): 197–221, https://doi.org/10.1023/B:MIND.0000021684.50925.c9; Brian Skyrms, *Signals: Evolution, Learning, and Information* (Oxford: Oxford University Press, 2010), 33–47.

49. Dretske, *Knowledge*, 65.

50. See Andrea Scarantino, "Information as a Probabilistic Difference Maker," *Australasian Journal of Philosophy* 93, no. 3 (2015): 419–43, https://doi.org/10.1080/00048402.2014.99366; Ulrich E. Stegmann, "Prospects for Probabilistic Theories of Natural Information," *Erkenntnis* 80, no. 4 (2015): 869–93, https://doi.org/10.1007/s10670-014-9679-9.

51. Bar-Hillel and Carnap, "An Outline of a Theory."

52. Some scholars argue that the so-called Bar-Hillel/Carnap Paradox is superficial (e.g., see Nir Fresco and Michaelis Michael, "Information and Veridicality: Information Processing and the Bar-Hillel/Carnap Paradox," *Philosophy of Science* 83, no. 1 [2016]: 131–51, https://doi.org/10.1086/684165) and that Floridi confuses information with informativeness (see Marie Duzi, "The Paradox of Inference and the Non-triviality of Analytic Information," *Journal of Philosophical Logic* 39, no. 5 [2010]: 473–510, https://doi.org/10.1007/s10992-010-9127-5). Even though their arguments are correct, I believe that Floridi's theory of strongly semantic information has its own value for its supposed function.

53. Floridi, "Outline," 197–221.

54. In Skyrms, *Signals*, 40. He notes, "For different games, the content vector shows how the signal moves probabilities of different states, or different acts."

55. Gregory Bateson, *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology* (Chicago: University of Chicago Press, 1972).

56. Scarantino, "Information."

57. Bateson, *Steps*, 453.

58. Deacon, *Incomplete Nature*, 332.

59. Ruth Garrett Millikan, *Language, Thought, and Other Biological Categories: New Foundations for Realism* (Cambridge, MA: MIT Press, 1984), 95–114; Millikan, *Language: A Biological Model* (Oxford: Oxford University Press, 2005), 53–76.

60. Millikan, *Language, Thought*, 31–32; Ruth Garrette Millikan, "Biosemantics," *Journal of Philosophy* 86, no. 6 (1989): 281–97; Neander, *Mark of the Mental*, 52–56; Shea, *Representation*, 56–63.

61. Norbert Wiener, *Cybernetics: Or Control and Communication in the Animal and the Machine*, 2nd ed. (Cambridge, MA: MIT Press 1961), 132.

62. Wiener draws on the Landauer principle, which asserts that a bit of information requires at least kT ln2 energy. See R. Landauer, "Irreversibility and Heat Generation in the Computing Process," *IBM Journal of Research and Development* 5, no. 3 (1961): 183–91, https://doi.org/10.1147/rd.53.0183.

63. See Talcott Parsons, *The Social System* (Glencoe, IL: Free Press, 1951); Niklas Luhmann, *Soziale Systeme* (Frankfurt am Main: Suhrkamp, 1984), 148–90; Raf Vanderstraeten, "Parsons, Luhmann and the Theorem of Double Contingency," *Journal of Classical Sociology* 2, no. 1 (2002): 77–92, https://doi.org/10.1177%2F1468795X02002001684.

64. Mark Burgin, *Theory of Information: Fundamentality, Diversity and Unification* (Singapore: World Scientific Press, 2010), 412.

65. Burgin, 414, 421.

66. Millikan, *Language, Thought*; Millikan, *Varieties*; Millikan, *Language: A Biological Model*.

67. David Lewis, *Convention: A Philosophical Study* (Cambridge, MA: Harvard University Press, 1969); Skyrms, *Signals*.

68. André De Tienne, "Information in Formation: A Peircean Approach," *Cognitio* 6, no. 2 (2005): 149–65; Winfried Nöth, "Charles S. Peirce's Theory of Information: A Theory of the Growth of Symbols and of Knowledge," *Cybernetics and Human Knowing* 19, no. 1–2 (2013): 137–61; James Jakób Liszka, "How Signs Convey Information: A Peircean Approach," *Chinese Semiotic Studies* 12, no. 1 (2016): 45–66, https://doi.org/10.1515/css-2016-0005.

69. Floridi, *Information*, 46–79.