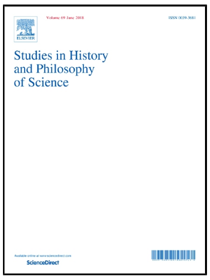

No communication without manipulation: a causal-deflationary view of information

Cristian Ariel López, Olimpia Iris Lombardi

PII: S0039-3681(17)30276-5

DOI: 10.1016/j.shpsa.2018.06.003

Reference: SHPS 1392

To appear in: *Studies in History and Philosophy of Science*

Received Date: 12 November 2017

Accepted Date: 07 June 2018

Please cite this article as: Cristian Ariel López, Olimpia Iris Lombardi, No communication without manipulation: a causal-deflationary view of information, *Studies in History and Philosophy of Science* (2018), doi: 10.1016/j.shpsa.2018.06.003

TITLE PAGE

No communication without manipulation: a causal-deflationary view of information

Cristian Ariel López

University of Buenos Aires – University of Lausanne – CONICET

Av. Du Tribunal-Fédéral 40, 33, 1005, Lausanne, Switzerland

lopez.cristian1987@gmail.com

Olimpia Iris Lombardi

University of Buenos Aires – CONICET

3880 Crisólogo Larralde, Capital Federal, Argentina

olimpiafilo@arnet.com.ar;

olimpiafio@gmail.com

Acknowledgements

We are extremely grateful to Christopher Timpson for discussions of the ideas and arguments contained within this paper. Previous versions of our work were presented at *International Workshop "What is Quantum Information?" (*Buenos Aires, 2015*)* and at the *XXV Biennial Meeting of the Philosophy of Science Association* (Atlanta, 2016) and we thank the audience members for several helpful suggestions. We would also like to thank the three anonymous referee: their advices and remarks have substantially improved our work. Finally, special thanks to all members of Group of Philosophy of Science of the University of Buenos Aires (Faculty of Mathematics and Natural Science) for their continuous support. This work was supported by the grant 57919 from the John Templeton Foundations, by a Large Grant of the Foundational Questions Institute (FQXi) and by a Grant of the National Council of Scientific and Technological Research (CONICET).

No communication without manipulation: a causal-deflationary view of information

Abstract

In this paper, we shall describe a new account of information in communicational contexts, namely, a *causal*-deflationary one. Our approach draws from Timpson's deflationary view and supplies the field of philosophy of information with new tools that will help to clarify the underlying structure of communication: information is an abstract entity that must be involved in a *causal* link in order to achieve communication. In light of our account, communication is not merely the existence of statistical correlations between source and receiver, as usually understood from a purely formal view. Instead, communication is an asymmetric phenomenon involving causal notions: the destination system must be able to be *causally* manipulated by intervening on the source for successful communication. In a nutshell, we shall support the following lemma: no communication without manipulation.

Keywords: information; communication; causation; manipulation

1. Introduction

The philosophy of information is nowadays at its height. In the last years, it has grown stronger as an autonomous field of philosophical analysis. This fact is not surprising when one considers that 'information' is currently one of the most common and used terms, one that pervades many domains, from everyday language to quantum mechanics. Its ubiquitous presence is perhaps one of its hardest features to deal with. As Luciano Floridi (2016: 1) claims, information "is notoriously a polymorphic phenomenon and a polysemantic concept".

In this present-day context, the philosophy of information is increasingly growing in varied directions. Much philosophical work has been devoted to elucidate the concept of information (see, e.g., Duwell 2003, 2008; Lombardi 2004; Timpson 2004, 2013; Floridi 2011, 2016; Lombardi, Fortin, and Vanni 2015). In particular, much light has been shed on the matter by looking into its uses in communicational situations, mainly in the field of information and communication technologies (ICTs). Framed within the ongoing communicational revolution, the elucidation of the concept of information in terms of data communication has gained relevance in the philosophical literature, especially grounded on the mathematical theory of communication pioneered by Claude Shannon (1948): Shannon's theory has become the traditional starting point for the philosophical understanding of the concept of information.

One of the clearest and more fruitful approaches to information available in the philosophy of physics is Christopher Timpson's deflationary view (Timpson 2004, 2013). Even though this work aims at discussing the status of quantum information, in the outset it introduces general considerations about information, particularly in terms of Shannon's theory. Arguing against any physical or substantial interpretation of information (Landauer 1991, 1996; Rovelli 1996), Timpson denies that any new kind of substance or stuff is being added to our catalogue of physical entities by the term 'information'. From this ontologically deflationary viewpoint, all that is required for communication to be successful is that the destination of the information reproduces a token of the same type as that corresponding to the token produced at the source. Thereby, information as data communication is fundamentally a type generated by an information source, and communication basically consists in realizing a single pattern or structure in different instances. To put it in another way, communication is fundamentally the reproduction of a pattern realized by tokens of the same type.

Timpson is on the right track by pointing out that no new stuff is introduced into the world by the word 'information'. His work is also particularly insightful as it introduces a "causal parlance" in the communication context by means of the notion of "*re*-production". However, the point we want to make is that the relevance of such a causal notion has not been sufficiently stressed: apart from a few marginal remarks about production or causation in communication, Timpson's definition of information does not rely on them, nor is causation a central issue in his philosophical inquiry either. Likely, this is due to his interest in clarifying the semantics and ontology of the very notion of information, arguing against substantivalist approaches. Notwithstanding this fact, we think that in order to fully capture and to properly conceptualize the causal nature of information as data communication, a deeper and systematic analysis is required. The aim of this paper is to further develop the deflationary view by supplying it with causal tools that will help to clarify the underlying structure of communication. The resulting view is a *causal*-deflationary account of information. According to this new approach, transmission of information is fundamentally an asymmetric phenomenon mounted on a causal structure: for successful communication, the destination system must be able to be *causally* manipulated from the source. In a nutshell, we shall support the following lemma: no communication without manipulation.

2. Information in communication: Shannon's theory in perspective

As mentioned above, information is a polysemantic concept. The plurality of definitions and uses of the term 'information', across several domains, discourages any attempt to reach an all-embracing concept of information. As Claude Shannon stressed:

> "The word 'information' has been given different meanings by various writers in the general field of information theory. It is likely that at least a number of these will prove sufficiently useful in certain applications to deserve further study and permanent recognition. It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general field." (Shannon 1993: 180)

Being so, any philosophical approach to the subject should start off by sorting out the many imprecise senses in which information is considered.

To begin with, one of the most general distinctions usually drawn up is that between an *everyday* or *semantic* sense of information and a *technical* or *statistical* sense (for this distinction, see, e.g., Timpson 2004, 2013). According to the first one, information is something that bears semantic content and, so, it is closely related to notions such as meaning, truth, and knowledge (Bar-Hillel and Carnap 1953, Bar-Hillel 1964). From a semantic perspective, Luciano Floridi (2011, 2016) takes the notion of data as the starting point, because it is less rich and slippery than the notion of information: a piece or instance of information is meaningful well-formed data.

The concept of information in its statistical sense, on the contrary, focuses on the quantifiable features of information, independently of any content; it is strongly associated with a mathematical vocabulary. Accordingly, statistical information can be studied in at least two different contexts. In a *computational* context, the relevant quantitative concept is algorithmic complexity, which measures the minimum resources needed for an individual message to be effectively reconstructed and stored (Solomonoff 1964; Kolmogorov 1965, 1968; Chaitin 1966). In the present article we will be interested only in the *communicational* context, where information is essentially something that can be transmitted for communication purposes: Shannon's "Mathematical theory of communication" (1948) is the classical source in this context.

In his 1948 paper, Shannon offers precise results about the resources needed for optimal codification and for error-free communication. Specifically, in Shannon's theory the following elements are formally introduced:

- A *source S* as the system that produces information. *S* has a range of possible states s_i, usually called *letters*, and generates sequences of letters. Each letter is assigned with a probability $p(s_i)$ that defines its frequency in the sequence.
- A *destination D* as a system that receives the information produced at the source. *D* is also characterized in terms of its possible states d_j, each one with its probability $p(d_j)$.
- The correlations between *S* and *D*, as expressed by the conditional probabilities $p(d_j / s_i)$.

With these elements, the information produced at the source by the occurrence of letter s_i and the information received at the destination by the occurrence of letter d_j can be respectively defined as:

$$H(s_i) = -\log p(s_i) \qquad\qquad H(d_j) = -\log p(d_j)$$

On this basis, the Shannon *entropies* of the source and the destination are defined as the average amount of information produced at the source and the average amount of information received at the destination, respectively:

$$H(S) = -\sum_{i=1}^{n} p(s_i) \log p(s_i) \qquad\qquad H(D) = -\sum_{j=1}^{m} p(d_j) \log p(d_j)$$

In turn, the *mutual information* $H(S;D)$, conceived as the average amount of information produced at the source and received at the destination, is defined as

$$H(S;D) = -\sum_{i=1}^{n} \sum_{j=1}^{m} p(s_i, d_j) \log \frac{p(s_i) p(d_j)}{p(s_i, d_j)}$$

where $p(s_i, d_j) = p(s_i) p(d_j / s_i)$ is the joint probability of s_i and d_j.

Though the ideal of communication is that mutual information be maximum (that all the information generated at the source, and only that, be received at the destination), real situations are rather different because of equivocity and noise. Usually, *equivocity E* is defined as the average amount of information produced by *S* but not received at *D*, and *noise N* is defined as the average amount of information received at *D* but not produced by *S*:

$$E = H(S) - H(S;D) \qquad\qquad N = H(D) - H(S;D)$$

As situations involving noise and equivocity are the rules instead of the exception, in practice much effort is devoted precisely to reduce equivocity and noise to a minimum. The success of Shannon's theory precisely consisted in identifying the conditions needed for error-free transmission of information to be possible.

The simplicity of Shannon's theory could give the impression that a clear conceptual definition of the notion of information can be drawn from it. However, things are not that straightforward. So far, information remains as an entirely abstract concept, capable of being applied practically everywhere (see discussion in Lombardi, Fortin, and Vanni 2015). In spite of the terms used to name the different magnitudes defined above, in principle nothing in the theory establishes a link between the mathematical symbols with communication-related concepts. In fact, present-day textbooks usually introduce the theory in a completely formal way, with no mention of sources and destinations, and the basic concepts are defined in terms of random variables and probability distributions over their possible values. Only when the formalism has been presented, the theory is applied to the traditional case of communication (see, e.g., Cover and Thomas 1991). Therefore, if we want to philosophically elucidate what communicational information is or what is going on during communication, we need to interpret the bare formal apparatus. And this, in turn, requires identifying the essential elements of communication.

3. Elucidating communication

As we are dealing with a quite abstract notion of communication, devoid of any semantic dimension, the characterization of communication we will offer in this section focuses on its general features within the field of information and communication technologies. That is, our analysis of communication has nothing to do with those approaches closely tied up to natural language or human communication (e.g., Grice 1957, 1989; Korta and Perry 2015). In this framework, two notes are essential for communication: asymmetry and production.

3.1. Communication as an asymmetric process

Despite Shannon's theory being originally proposed in the context of communication engineering, it can be formulated in exclusively formal terms, as a chapter of the theory of probability (Khinchin 1957; Reza 1961; Cover and Thomas 1991). From this perspective, instead of a source and a destination, we have two discrete random variables X and Y with alphabets A and B, and probability mass functions $p(x)=\Pr(X=x)$, with $x \in A$, and $p(y)=\Pr(Y=y)$, with $y \in B$, respectively. The entropies $H(X)$ and $H(Y)$ of the variables X and Y can be computed. Moreover, what we originally called 'equivocation' E and 'noise' N now become the conditional entropies $H(X/Y)$ and $H(Y/X)$ respectively, and the mutual information $H(X;Y)$ turns out to be a measure of the correlations between the variables X and Y. In this presentation, the described situation is completely symmetric: nothing endows a variable with logical priority over the other. This might lead one to conclude that communication is a symmetric process, but such a conclusion would ignore one of the essential elements of communication.

As Shannon explains in his classical paper:

> "The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point […] the significant aspect is that the actual message is one selected from a set of possible messages." (Shannon 1948: 379)

In other words, a message is selected at the source from a set of possible messages, and the goal of communication consists in *identifying* at the destination the message produced at the source: the source and destination roles are clearly different and, as a consequence, they cannot be swapped without modifying the whole situation. In turn, given the source and the destination, from an exclusively formal viewpoint, the communication channel can be defined in terms of the conditional probabilities $p(d_j/s_i)$ or the conditional probabilities $p(s_i/d_j)$, to the extent that they are inter-definable: $p(d_j/s_i)p(s_i)=p(s_i/d_j)p(d_j)$. Nevertheless, from the communication viewpoint, the channel clearly allows distinguishing the two directions in the process, as one of the channel's ends depends on the other:

> "A communication channel is a system in which the output depends probabilistically on its input. It is characterized by a probability transition matrix that determines the conditional distribution of the output given the input." (Cover and Thomas 1991: 6)

A formal result of Shannon's theory makes explicit the asymmetry of communication. Stated in informal terms, the *data processing inequality* (Cover and Thomas 1991; Yeung 2002) expresses the fact that information cannot be created *ex nihilo*. More technically, information in communication cannot be generated by local operations at the destination; in other words, post-processing cannot increase the amount of information received. In the situation described above, let us consider a third variable Z whose value depends probabilistically only on Y, that is,

$p(z/x,y) = p(z/y)$; in this case, the random variables *X*, *Y*, and *Z* are said to form a Markov chain, $X \rightarrow Y \rightarrow Z$. The data processing inequality states that, if *X*, *Y*, and *Z* form a Markov chain, then *Z* cannot have more information about *X* than *Y* has about *X*, that is, $H(X;Z) \leq H(X;Y)$.

Furthermore, the asymmetry of the process can also be understood by considering the difference between equivocity and noise. Recall that, in the case of equivocity, there are states of the destination that are correlated with more than one state of the source and, in the case of noise, there are states of the source correlated with more than one state of the destination. Textbooks on Shannon's theory usually represent this difference graphically as follows:

Equivocal case

Noisy case

Figure 1: Difference between equivocity and noise

Although these two situations seem to be mirror-image twins expressing the symmetry of the situation, this is not the case when communication is seriously considered. As one of the goals of communication is *to identify* at the destination the message produced at the source, equivocity and noise are not equally serious. In fact, as Figure 1 shows, noise does not preclude the identification of the state produced at the source by means of the state occurred at the destination. On the contrary, equivocity blocks such identification, since the state occurred at the destination may come from more than one state of the source. In this sense, equivocity is a far more serious obstacle to communication than noise.

3.2. Communication as a difference-maker process

Up to this point, communication has been characterized as an asymmetric process: there is a source that produces messages, and a destination where the messages are identified. However, asymmetry alone is not sufficient to grasp the specificity of communication.

Let us consider a transmitter *T* broadcasting an electromagnetic signal, which is received by two television sets, TV_1 and TV_2. In principle, one might regard TV_1 as the source of information and TV_2 as the destination where the states of the source must be identified. If both TV_1 and TV_2 are tuned in on the same TV-channel, the identification will certainly be successful: a person watching

TV_2 will perfectly know what is TV_1 displaying. Shannon's formalism can be applied to this situation, since a channel can be defined between TV_1 and TV_2. Thus, some authors would consider that information is transmitted between the two TV-sets: "there is a channel between these two points, and information passes between them, even if there is no direct physical link joining [them]." (Dretske 1981: 38).

However, one might think that the case of the TV-sets tuned in on the same channel is not a legitimate case of communication. Indeed, the asymmetry between source and destination seems to be the result of a conventional choice and not of an intrinsic feature. This means that the probabilistic dependence of the destination's states upon the source's states should not only imply asymmetry, but should also reveal a stronger link between the two sets of states. Communication requires that what happens at the source, that is, the selection of a message from the set of possible messages, *produces* a specific modification on the destination regarding its state. In other words, communication is a process that "makes a difference" at the destination.

The so-called "difference-making" idea is most often articulated in counterfactual terms: it is based on figuring out what would have happened if an event had not taken place (Menzies 2004). An event makes a difference when it affects the occurrence of another event: without the first event, the second one would not have occurred. In the communicational context, a difference at the destination (that is, a change in its state) is only possible because something happened at the source (in particular, a certain state was produced), and nothing would have happened at the destination if nothing had happened at the source.

4. Timpson's deflationary view of information

So far, we have narrowed our focus down to a statistical concept within a well-defined formalism, framed in a communicational context. Despite the elucidatory work developed up to this point, information in communication is still a too-abstract notion to be philosophically substantive. As Shannon's theory is a formal apparatus that concerns average quantities and statistical correlations between systems' states, the very concept of information still remains bare: we need to put flesh on it. Certainly –and there is some agreement on this – it is not possible to obtain a philosophically rich concept of information from a purely mathematical theory. So, even though Shannon's theory is the starting point to elucidate information as data communication, we now need to *interpret* it.

There are many and varied interpretations of Shannon information in the current literature. A good strategy to start is to firstly dispose of more problematic interpretations. The first one to discard is the semantic interpretation, since semantic matters play no role when the statistical sense of information is at issue. As Shannon famously nails it down:

> "Frequently the messages have *meaning*; that is, they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem." (Shannon 1948: 379)

In other words, whether messages produced by an information source bear meaning or not does not matter: "semantics lies outside the scope of mathematical information theory" (Cherry 1951: 383).

Secondly, as sources and destinations are always physical devices, and transmission of information unavoidably requires physical implementation, it might seem natural to consider that Shannon information refers to something physical. Deeply ingrained in physicists' and engineers' minds, the physical interpretation of information conceives Shannon entropy, and the associated quantities, as physical magnitudes, which, as such, always need a physical implementation:

> "[I]nformation is not a disembodied abstract entity; it is always tied to a physical representation. It is represented by engraving on a stone tablet, a spin, a charge, a hole in a punched card, a mark on a paper, or some other equivalent." (Landauer 1996: 188)

Accordingly, transmission of information between two points of the physical space necessarily requires an information-bearing signal, to wit, a physical process propagating from one point of space to another (see Landauer 1991, 1996; Rovelli 1996; for a detailed discussion, see Lombardi, Holik, and Vanni 2016).

Although very appealing, the physical interpretation of Shannon information falls short in some noteworthy aspects. From a conceptual viewpoint, the inference from the need of the physical embodiment of information to its physical nature is a *non sequitur*: the fact that physical systems are required to store or to transmit information does not imply that information in itself is a physical entity. Consider, as an analogy, the discussions about the ontological status of mind: even if it seems to be quite obvious that mind requires a physical support (paradigmatically, a brain), this does not straightforwardly imply that mind is physical in its own nature without assuming a strong reductionist stance.

But the strongest challenge to the physical interpretation is that given by certain quantum processes, which are conceived as communicational protocols of transmission of information. In particular, entanglement-assisted communication, teleportation being its paradigmatic example (see, e.g., Nielsen and Chuang 2000), seems not to involve information-bearing signals (we will come back to this case below). This kind of situation has lead certain physicists, tightly tied to a physical view of information, to supply twisted explanations invoking particles traveling towards the past (e.g., Jozsa 1998; Penrose 1998) or hiding great amounts of information (Deutsch and Hayden 2000). It is precisely this challenge which Christopher Timpson intends to face.

4.1. No new stuff in the world

If ‘information’ does not refer to something semantic or physical in nature, what is it? Is it perhaps nothing at all? Before endorsing some kind of nihilism, there is a third option. By drawing on insights from philosophy of language, metaphysics, and philosophy of science, Timpson (2004, 2013) proposes a general elucidation of the concept of information, and applies his work to quantum information and its relevance for the foundations of quantum mechanics. Since we are interested in the general concept of information, we will set the problem of quantum information aside.

After distinguishing between the everyday notion of information and the technical concept, and stressing that he will focus on the technical concept, denoted by ‘*information$_t$*’, Timpson supplies the following definition:

> “Information$_t$ is what is produced by an information$_t$ source that is required to be reproducible at the destination if the transmission is to be counted a success.” (2013: 22)

where an *information$_t$ source* is a system that produces messages, that is, sequences of letters under the form of states. The general aim of Timpson’s strategy is to defend the idea that information is an abstract item and, as a consequence, the thesis that there is nothing in the physical world called by the name ‘information’.

So, in order to support his thesis, Timpson introduces a distinction between *bits* and *pieces* of information. While it is usually said that Shannon information is concerned with bits (which measure the resources needed for an efficient transmission of messages), Timpson claims that Shannon’s theory also specifies “what pieces of information are” and, thus, it is a theory about pieces of information as well (Timpson 2013: 16). Armed with this distinction, Timpson is able to argue that Shannon information is an abstract entity, both *qua* quantity (as an amount of the required resources to transmit messages) and *qua* piece of information (as what is produced by a source).

The argument for the "abstractness" of information *qua* quantity runs as follows: quantities are abstract to the extent that they are mathematical items that measure a certain measurable property. In particular, information *qua* quantity measures the "maximum amount that messages consisting of letters produced by a source can be compressed" (Timpson 2013: 22). As mathematical items are supposed to be abstract, information *qua* quantity is abstract as well.

As to the argument for the abstractness of information *qua* pieces, it relies, in turn, on a second distinction, namely, the metaphysical distinction between *types* and *tokens*. Although disputable, in general the type-token distinction refers to the difference between a general sort of thing and its particular concrete instances (Wetzel 2008). Timpson turns to this distinction to point out the difference between "the concrete systems that the source outputs and the type that this output instantiates" (Timpson 2004: 22).

Let us consider a particular message that the information source outputs, that is, a particular sequence of letters corresponding to the source's states. According to Timpson, the goal of communication is that such a sequence be reproduced at the destination. Here is where the type-token distinction comes into play:

> "But what, we might finally ask, *is* the piece of information$_t$ that the source produces that we desire to transmit? Yes, it's what is produced by the source – a sequence – but do we mean the sequence type or the sequence token? The answer is quick: it is the type" (Timpson 2013, 23).

To put it differently, successful communication only requires that "another token of this type actually be produced at a distant point"(Timpson 2013: 23). This means that what is transmitted, to wit, information *qua* pieces, is a type-sequence. From here, the conclusion is straightforward: since types are abstract, information *qua* pieces is also an abstract entity.

Accordingly, transmission of information does not involve the flow of any substance or stuff travelling from one point of the physical space to another. This is the reason why Timpson call his view '*deflationary*': Shannon's theory does not add new stuff into the world, but it is only concerned with abstract objects (information *qua* pieces) and with a measure of the channel's resources required to send a message (information *qua* bits).

The type-token distinction leads Timpson to another idea which, although briefly mentioned in his book, is particularly relevant. The distinction can be generalized in terms of patterns and structures:

> "[T]he distinction may be generalized. The basic idea is of a pattern or structure: something which can be repeatedly realized in different instances; and perhaps realized in different media." (Timpson 2013: 18)

Given that what is actually sent along in communication is not a concrete thing (i.e., a token-sequence), but an abstract type-sequence, then communication is based on reproducing at the destination the same pattern that was produced by the source. Communication essentially requires the mapping of a structure or pattern generated by a source onto the destination, which goes along the line of Armond Duwell's previous claims:

> "The most natural way to think about success internal to the Shannon theory is to have a one-one mapping from the set of symbols that characterize the source to the set of symbols that characterize the destination. This mapping establishes an identity between the symbols that characterize the source and destination […]. In other words, this function establishes the appropriate conditions for token instantiation of the type that the information source produced tokens of." (Duwell 2008: 200)

4.2. Reproduction as a *causal* notion

In Timpson's account, information and communication are not very explicitly connected to causation. However, by characterizing communication in terms of "reproduction of a pattern or structure", his deflationary view involves, in some sense, a certain causal idea lying behind the process of transmitting information. The point is particularly appealing, as long as it allows getting rid of mere statistical correlations as genuine communicational situations, unlike what a literal reading of the formalism might allow. Let us consider the exceptional case of two unrelated lotteries that generate, during a certain period, the same sequence of random results. When Shannon's theory is introduced in a completely mathematical way, in terms of random variables and probability distributions over their possible values, it can be used to model that situation. Nevertheless, it is clear that this case fails to be communicational, as it evidently lacks both asymmetry and difference-making. This means that the idea of mere statistical correlations between source and destination is too broad, and therefore it allows characterizing as communicational certain cases that clearly do not involve transmission of information.

This seems to have been noticed by Timpson when, in a quick and underdeveloped statement, he explains:

> "What will be required at the end of the communication protocol is either that another token of this type actually be produced at a distant point (as a consequence of the production of the initial token); or at least that it be possible to produce it here (as a consequence of the initial production) by a standard procedure." (Timpson 2013: 23)

The comment is completed in a footnote on the same page:

> "The parenthetical clauses are important as they capture the idea that we genuinely have transmission, rather than just random production of tokens of the same type: that would not count as a transmission of information$_t$." (Timpson 2013: 23, footnote)

Timpson is clearly trying to rule out situations like that of the random coincidence between lottery results as cases of transmission of information. The notions of "reproduction" and "being a consequence of" effectively point in that direction. Nevertheless, a deeper analysis in terms of the causal nature of such reproduction (as well as its role in communication contexts) is missing in Timpson's account. Furthermore, although causality is already presented in an embryonic form in the deflationary view, the very approach is not based on it at all. We think that both the causal notion already involved in the term "reproduction" and its relevance to elucidate the notion of information require a further and a deeper development since, according to our viewpoint, they are crucial for understanding information *in* communication. It is quite clear that the elucidation of the concept cries out for a philosophical analysis of the relationship between source and destination in cases of communication. What we need is to unfold and dig into the relation characterized by Timpson as 'being the consequence of', and to approach information in communication stressing its causal elements. This will allow us to arrive at the *causal*-deflationary view of information we stand for. This is precisely what we will do in the following section.

5. No communication without manipulation

The above-considered remarks on Timpson's deflationary view imply that the proposal needs to be complemented in order for it to be capable of properly displaying the assumed causal structure. Moreover, such causal elements need to be sharpened. Our project requires unfolding what "being a consequence of" exactly means. We will thus offer a reliable criterion to identify genuine instances of communication on the basis of the very causal structure of any communicational situation.

5.1 Elucidating causation as manipulability

Admittedly, our approach is not the first that links information and causation: a number of philosophers have thought of causation as transmission of information. The idea was probably first introduced by John Collier (1999) in explicit terms, who sought to conceive causation fundamentally as an information-transmission process. In Collier's own words: "the basic idea is that causation is the transfer of a particular token of a quantity of information from one state of a system to another" (Collier 1999: 215; see also McKay 2010). Later on, Collier's view influenced the emergence of a new brand of structural realism – 'information-theoretic structural realism' (see James Ladyman and Don Ross 2007; Luciano Floridi 2008).

In any case, we will not take that direction of the elucidatory arrow. We do not want to elucidate causation in terms of information, but the other way around: information in terms of causation. To our knowledge, the road has not been traveled yet in this opposite direction. Thus, in order to avoid misunderstandings, we need to make perfectly clear what our proposal does not intend to render. Firstly, (a) we will not argue that information *is* causation in some fundamental sense and, secondly, (b) at the end of the day, we will remain neutral with respect to what causation ontologically is. No doubt these are greatly interesting points, but they are not our concern in this section. Our main goal here is to provide a strong and reliable criterion that allows us to bare the causal structure underlying the transmission of information.

Causation is a tough nut to crack. Problems around the nature of causation, how to justify causal relationships (if there are any), etc., have gone on throughout the entire history of philosophy from Aristotle, and still remain broadly debated. In general, a wide panoply of approaches can be found in the literature, such as regularity theories (inspired by Hume (2000 [1748]), counterfactual theories (Lewis 1973), physical theories (Fair 1979; Dowe 2000), and universals-based theories (Armstrong 1983). Even the idea of completely wiping out the word 'cause' from our scientific vocabulary has its advocates (as famously proposed by Bertrand Russell 1912). We will not go into the details about causation and its different approaches, since such an exegesis is widely beyond the scope of this paper. What we need is only an account with broad applicability to causal claims in multiple areas of science.

Regardless of the many highly sophisticated theories of causation, people act day-to-day steered by the tacit belief there are actual causal relationships in the world. Most of us are able to identify direct causal relationships and to distinguish them from correlations that are merely accidental or due to common causes – anyone can easily distinguish the pain of a finger due to a hammer blow from the showing up of the paperboy when the sun comes up every morning. Similarly, in science, a chemist distinguishes the kind of action that a catalyst performs in increasing the rate of a reaction from the mere correlation between the melting point and the color of an element. But what is this intuitive distinction grounded in?

One of the most recognizable features of causation is the capacity of control and manipulation it makes possible. Nancy Cartwright (1979) has already stressed this central feature by asserting that causal relationships are needed to ground the distinction between effective and ineffective strategies: an effective strategy proceeds by intervening at a system in order to obtain a desired outcome, and this is possible if and only if a causal relationship holds. To put it differently, causal relationships but not mere correlations are exploitable by us in order to bring about a certain outcome (Frisch 2014).

Manipulability accounts of causation have sought to systematically capture this intuitive feature of causal relationships. Offering a far-reaching account that applies to a wide variety of causal claims, both in different areas of science and in ordinary life, the basic idea of the manipulability accounts is that causal relationships are those "potentially exploitable for purposes of manipulation and control" (Woodward 2003: 25). Early versions of the manipulability theories (von Wright 1971), as well as some recent versions advocated by Huw Price and Peter Menzies (Price 1991, Menzies and Price 1993), appeal to the notion of free-agency in order to support a reductive approach to causation. However, due to the many criticisms that the free-agency theories have received (such as those of circularity or anthropocentrism – see Woodward 2013 for further details), a new non-reductionist version of the manipulability account of causation has been brought up: the *interventionist version*. Mainly supported by James Woodward (2003, 2007) and Judea Pearl (2009), this version starts by assuming that causation is a primitive notion that cannot be reduced to simpler and more basic concepts – such as that of agency (Woodward 2013). On this basis, the aim of the interventionist approach is not to define causation in terms of non-causal notions but to delimitate the domain of causation by means of the possibility of control and manipulation.

What is a causal relationship? What does '*X* causes *Y*' mean? From the manipulability view, '*X* causes *Y*' means, roughly, that we can manipulate *Y* (the *effect*) by manipulating *X* (the *cause*). In other words, we can modify something in *X* in such a way that there is a change in *Y*, and this enables us to control it. More precisely:

> "The claim that *X* causes *Y* means that, for at least some individuals, there is a possible manipulation of some value of *X* that they possess, which, given other appropriate conditions (perhaps including manipulations that fix other variables distinct from *X* at certain values) will change the value of *Y* or the probability distribution of *Y* for those individuals." (Woodward 2003: 40).

Two elements are central in Woodward's theory (2003: 39). The first one is the view of causal relationships as relating *variables*, which supplies a clear identification of the relata of the relation under study. The second element is the characterization of an intervention as a *change in the value of a variable*. This allows Woodward to capture, in a non-anthropocentric language, the idea of manipulating the value of *X* in order to determinate whether *X* causes *Y* by means of an ideal experiment. In this sense,

> "the intuitive idea is that an intervention on *X* with respect to *Y* changes the value of *X* in such a way that if any change occurs in *Y*, it occurs only as a result of change in the value of *X* and not from some other source." (Woodward 2003: 14).

Naturally, the notion of intervention is at the heart of Woodward's and Pearl's proposals. Informally, an *intervention* is a causal and exogenous process that allows stating whether the relationship between variables is a real, genuine cause-effect relationship. It is worth stressing that, in spite of an intervention being a causal event, there is no circularity whatsoever: the intervention as a causal event is used only to exhibit the causal relation between two sets of variables, none of which the intervening variable belongs to. An intervention acts directly on a variable working like a "switch" for the variable intervened on. In more precise terms, an intervention can be defined as follows (Woodward 2003: 98):

(i) *I* causes *X*.

(ii) *I* acts as a switch for all the other variables that cause *X*. That is, certain values of *I* are such that when *I* attains those values, *X* ceases to depend on the values of other variables that cause *X* and instead depends only on the value taken by *I*.

(iii) Any directed path from *I* to *Y* goes through *X*. That is, *I* does not directly cause *Y* and is not a cause of any causes of *Y* that are distinct from *X* except, of course, for those causes of *Y*, if any, that are built into the *I*-*X*-*Y* connection itself; that is, except for (a) any causes of *Y* that are effects of *X* (i.e., variables that are causally between *X* and *Y*) and (b) any causes of *Y* that are between *I* and *X* and have no effect on *Y* independently of *X*.

(iv) *I* is (statistically) independent of any variable *Z* that causes *Y* and that is on a directed path that does not go through *X*.

5.2 Linking manipulability to communication and information

Let us recall the argument developed up to this point. After having specified the sense of information under study and presented the basics of Shannon's theory in Section 2, in Section 3 we identified the essential notes of communication. Next, in Section 4, we presented one of the most promising current elucidations of the concept of information, Timpson's deflationary approach, showing that, despite already involving a certain causal vocabulary by talking about "reproduction of a pattern", the deflationary view does not get into details such as what notion of causation is endorsed, or what role causation plays in transmission of information. Accordingly, our proposal is to complement the deflationary approach to information with a sharper concept of causation based on manipulability, and to specify the key role that manipulation and causation play within the communicational context. Having set the basics of the manipulability view of causation, we can now put all those pieces together.

Roughly speaking, we are to support the idea that communication (thereby, all cases of transmission of information) relies on a causal structure of the communicational arrangement, which can be revealed by turning to the manipulability account of causation, particularly, to its interventionist version. As Mathias Frisch neatly puts it, "the results of interventions into a system are a guide to the causal structure exhibited by the system" (Frisch 2014, 78). Therefore, correlations that are merely accidental or due to a common cause, although introducing a mapping from source to destinations, are not enough for transmission of information: communication requires the possibility of controlling or producing a change in the destination by performing an intervention on the source. In other words, communication needs to meet the following Principle of Manipulability (PM):

> **PM**: For genuine communication, the possibility of identifying the states of the source by means of the states of the destination is not sufficient. In addition, it is necessary that the two sets of states be causally linked, in the sense that the states of the destination can be manipulated by interventions on the states of the source.

It is worth stressing that PM is not only meant to clarify the meaning of "being a consequence of", as Timpson used it, but also to highlight its causal features, representing a substantial addendum to the deflationary view of information. In fact, as we will see below, the so-obtained "causal-deflationary view" deals with ordinary communication situations in a more natural way.

Let us see briefly how PM should be applied to a concrete case. First of all, we can see that PM clearly demarcates the boundaries between accidental or common-cause correlations and genuine communicational situations. Recall the example consisting in a transmitter and two TVs sets (Section 3.2). When we focused on the possible correlations between TV_1 and TV_2, we noticed that, if we understand communication to be merely sameness of pattern or one-to-one mapping, then the situation should be counted as communicational, even when this is evidently not the case. From the causal-deflationary perspective, we can deal with such spurious cases; we only need to translate the situation to the manipulability language and look at what is going on from a causal point of view.

To begin with, take a look at the situation that involves the transmitter *T* (Figure 2).

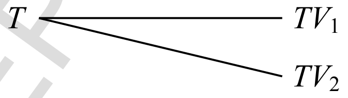

Figure 2: Causal relationships between T and TV sets

The question is whether there is communication (transmission of information) between *T* and the *TV* sets TV_1 and TV_2. According to PM, there will be communication if and only if we can manipulate some variable of the destinations by intervening on some variable of the source, that is, by changing the value of a source's variable. We can define two values for *T*, namely, "being turned on" ($T=1$) and "being turned off" ($T=0$). Likewise the *TV* sets may have the value "displaying a signal" ($TV=1$) and "not displaying any signal" ($TV=0$). Since the whole point from a communicational viewpoint is to find out whether or not there is a causal link between these two sets of variables, we define a possible intervention on T by switching $T=1$ to $T=0$ and by seeing whether or not we are able to manipulate the values of defined variables of TV_1 and TV_2. It is pretty simple to see what will happen: by intervening on T, by means of an exogenous switcher that "breaks" the alleged causal structure, the value of the variable T changes to 0 and the values of TV_1's and TV_2's variables change to 0 as well. Naturally, we have made sure that our TV_1 and TV_2 are isolated from any other cause (e.g., other more remote antenna). Therefore, we can claim that there is a causal relation between some states of the source (T) and some states of the destinations (TV_1 and TV_2) and, by virtue of PM, there is transmission of information from the transmitter to the *TV* sets.

5.3. Demarcating communication from non-communication

As mentioned before, the payoff conveyed by our proposal is twofold: not only does it deepen certain underdeveloped aspects of the deflationary view (giving us a better understanding of it), but it also endows it with tools to better deal with potentially spurious or counter-intuitive cases that we would not accept as communicational, providing clear demarcation criteria.

Let us consider again the previous example of the two TV sets. We can use the same strategy as before to determine whether or not there is transmission of information between TV_1 and TV_2. Going over the same ground, we define certain states as relevant and an intervention on the intended source. However, there is no possible intervention on TV_1 that allows us to manipulate TV_2's state. We could turn off TV_1 or even destroy it and nothing will happen on TV_2's states. Hence, even though there is a sameness of pattern between TV_1 and TV_2, and a perfect correlation between their states, there is no direct causal relation linking the two systems. Therefore, there is no communication, despite the fact that this situation could be mathematically modelled using Shannon's theory.

The same reasoning can be applied to other cases in order to evaluate whether or not communication takes place. All we need is to construe the situation in manipulabilist terms. And practically any intended communicational situation may be tested by devising different ways to intervene on a system's states and by seeing what is going on with other, correlated systems' states. What our causal-deflationary view yields is a far-reaching and systematic understanding of why mere statistical correlations do not constitute communicational situations. It is for this reason that our approach prevents cases of merely accidental or common-cause correlations (even if perfect) from being wrongly accepted as genuine situations of communication by exposing the causal structure underlying the transmission of information.

Although the above discussion illustrates how the PM strengthens the original deflationary view, those examples might be considered as too simple and obvious. This opinion, however, may be counterbalanced by taking into account further examples, in particular, cases involving quantum mechanics. Recall that Timpson's approach to information achieved its greatest success in its application to the so-called "entanglement-assisted communication". Therefore, the new causal view of information must show the same ability to deal with those cases.

To start with, we are going to consider an EPR experiment, where Alice and Bob perform measurements on their own particle of a pair in a maximally entangled state. As is well-known, the results obtained by Alice and Bob will be correlated, and the correlation will depend on the relationship between the observables measured on each particle. Nevertheless, as greatly discussed in the field of the foundations of quantum mechanics, EPR correlations cannot be interpreted as the consequence of a common cause (see, e.g., Hughes 1989). How can it be explained, then, that those correlations, despite being non-accidental and despite not sharing a common cause, cannot be used to transmit information? The causal-deflationist view of information supplies an answer to this question, which is completely independent from how the phenomenon is interpreted in physical terms: in EPR-experiments, no intervention on one end enables us to manipulate the result obtained in the other end. To put it clearer, Alice can do nothing on her own experimental arrangement to produce a specific modification in Bob's measurement result, and vice versa.

By contrast, teleportation is a protocol that, although based on quantum entanglement, adds a classical ingredient to make communication possible. Broadly speaking, an unknown quantum state $|\chi\rangle$ is transferred from Alice to Bob with the assistance of a shared pair of particles prepared in a maximally entangled state and of two classical bits sent from Alice to Bob (see, e.g., Nielsen and Chuang 2010). In the physics community, which is strongly tied to a physical interpretation of information, teleportation turns to be truly shocking: how can the information embodied in a quantum state be transferred without a signal traveling through space and carrying such information? Whereas several physicists have devised weird mechanisms to explain teleportation as a phenomenon of transmission of information, Timpson cuts the Gordian knot by means of his deflationary approach:

> "Once it is recognized that 'information' is an abstract noun, then it is clear that there is no further question to be answered regarding how information is transmitted in teleportation (…) for there is not a question of information being a substance or entity that is transported, nor of 'the information' being a referring term." (Timpson 2006: 599).

Nevertheless, this explanation does not make completely clear yet why teleportation *is* a case of transmission of information but an EPR-experiment *is not*. The idea of reproduction of a pattern, though on the right track, is silent about that point. Neither does it specify the causal structure involved in teleportation protocols. In other words, Timpson's view makes intelligible the transmission of information in situations whose communicational nature is already known or acknowledged, but it does not help us to explain why a situation is communicational in the first place.

The causal-deflationary approach completes the original deflationary view also in this sense. Though based on EPR correlations, teleportation is not merely an EPR-experiment. Indeed, in teleportation Alice not only has a particle of the entangled pair, but also has access to the state $|\chi\rangle$ to be teleported, and to the two two-state classical systems needed to send the two bits of information through the classical channel. As communication requires those three elements, the intervention does not need to act specifically on the entangled pair, but can operate on any of them. For instance, the intervention on Alice's particle may change the state to be teleported, from $|\chi\rangle$ to $|\varphi\rangle$: as a consequence, something changes in Bob's particle, as he will recover $|\varphi\rangle$ instead of $|\chi\rangle$. Or the intervention could be set to block one of the classical systems that Alice sends to Bob: in this case, Bob would be unable to recover the teleported state. It is worth stressing that the consequences of the interventions are well known on the basis of experimentally grounded reasons, independently of any interpretation of quantum mechanics.

Although teleportation is the traditional example of entanglement-assisted communication, the case of *superdense coding* is perhaps more interesting, since it does not require one to send anything other than qubits (two-state quantum systems). In a certain sense, superdense coding can be conceived as the inverse of teleportation: whereas in teleportation one qubit is transferred by sending only two bits, in superdense coding two bits are transferred by sending only one qubit. Let us suppose that, again, Alice and Bob share a pair of particles prepared in a maximally entangled state, but now Alice wants to send two classical bits of information to Bob. By applying locally one of four specific unitary operations on her own particle, Alice can transform the original entangled state into one of four possible orthogonal states (Bell states). Then, she sends her particle to Bob, who performs a measurement on the composite system: since the four possible states are orthogonal, he can distinguish by measurement the operation performed by Alice. Summing up, the superdense coding protocol makes it possible to encode two bits of information in a single qubit, with the condition that sender and receiver share an entangled state (see, e.g., Nielsen and Chuang 2010). In the superdense coding case, it is quite clear that communication depends on the manipulations performed by Alice at her end, consisting in applying one of four predetermined unitary operators. If, for instance, an intervention prevented Alice from making any of the operations on her own particle, or changed the specific operations that Alice performs, then Bob would be unable to identify the two bits she intended to send to him.

To sum up, in the communicational context information transfer requires the possibility of controlling the state of the destination by performing an intervention on the source. Does this mean that the concept of information itself is a causal concept? The answer is positive if a close conceptual link between information and communication is established: being transferred with communicational purposes would be an essential feature of information. However, such a close link could be rejected by arguing that, conceptually, information is prior to communication: whereas there may be information without communication, there may not be communication without information because communication is always information transfer. In other words, what the source produces is information independently of its being encoded or transmitted later. If the concept of information does not depend by definition on communication, then it can be applied also in non-communicational contexts, as in the computational context with its concept of algorithmic information. From this perspective, then, it is the concept of communication that is a causal concept, and this squares better with the deflationist view of information, since neither bits nor pieces of information are causal notions at all.

6. Conclusions

In this article we have developed a causal-deflationary view of information in the communicational context, according to which information is an abstract item *and* communication always involves causal links. This proposal does not intend to be an entirely new stance aiming to replace Timpson's view. On the contrary, it is an attempt to complement the original deflationist view by developing certain elements, already (though marginally) present in Timpson's work, in more precise causal terms. Nevertheless, this strategy does not undermine the deflationary character of the proposal, as the notion of causation appealed to can also be viewed as "deflationary", at least insofar it does not rely on a heavy metaphysical commitment, and causal relations do not need to be conceived as additional inhabitants of the ontology, but may be considered only in the light of their pragmatic role in manipulation and control.

This new preeminently causal approach clarifies the original deflationary view in two senses. First, by replacing the idea of "sameness of a pattern" for that of "patterns *causally* linked", it emphasizes the causal role of "reproduction of a pattern". It leads to a sharper and stronger concept of information in the communicational context, which is able to cope with tricky and unintuitive situations more naturally. Second, it improves the original view in the sense that, besides removing conceptual conundrums in communication situations well-known as such, it provides a probe to decide if a certain situation involves transmission of information on the basis of its manipulability features. We expect that our proposal, synthesized in the lemma "no communication without manipulation", paves the way for the application of the causal-deflationary view not only to physics, but also to other scientific fields, such as genetics and ecology, in which at present the concept of information also plays a highly relevant role.

Acknowledgments: We are extremely grateful to Christopher Timpson for discussions of the ideas and arguments contained within this paper. Previous versions of our work were presented at the *International Workshop "What is Quantum Information?" (*Buenos Aires, 2015*)* and at the *XXV Biennial Meeting of the Philosophy of Science Association* (Atlanta, 2016) and we thank the audience members for several helpful suggestions. We would also like to thank the three anonymous referees: their advice and remarks have substantially improved our work. Finally, special thanks to all members of the Group of Philosophy of Science of the University of Buenos Aires (Faculty of Mathematics and Natural Science) for their continuous support. This work was supported by Grant 57919 from the John Templeton Foundation, by a Large Grant of the Foundational Questions Institute (FQXi) and by a Grant of the National Council of Scientific and Technological Research (CONICET).

References

Armstrong, D. (1983). *What Is a Law of Nature?* Cambridge: Cambridge University Press.

Bar-Hillel, Y. (1964). *Language and Information: Selected Essays on Their Theory and Application*. Reading, MA: Addison-Wesley.

Bar-Hillel, Y. and Carnap, R. (1953). "Semantic information." *The British Journal for the Philosophy of Science*, **4**: 147-157.

Cartwright, N. (1979). "Causal laws and effective strategies." *Noûs*, **13**: 419-37.

Chaitin, G. (1966). "On the length of programs for computing binary sequences." *Journal of the Association for Computing Machinery*, **13**: 547-569.

Cherry, E. C. (1951). "A history of the theory of information." *Proceedings of the Institute of Electrical Engineers*, **98**: 383-393. Reprinted with minor changes as 1952, "The communication of information", *Scientific American*, **40**: 640-664.

Collier, J. (1999). "Causation is the transfer of information." Pp. 215-263, in H. Sankey (ed.), *Causation, Natural Laws, and Explanation*. Dordrecht: Kluwer.

Cover, T. and Thomas, J. (1991). *Elements of Information Theory*. New York: John Wiley & Sons.

Deutsch, D. and Hayden, P. (2000). "Information flow in entangled quantum systems." *Proceedings of the Royal Society of London A*, **456**: 1759-1774.

Dowe, P. (2000). *Physical Causation*. New York: Cambridge University Press.

Dretske, F. (1981). *Knowledge & the Flow of Information*. Cambridge MA: The MIT Press.

Duwell, A. (2003). "Quantum information does not exist." *Studies in History and Philosophy of Modern Physics*, **34**: 479-499.

Duwell, A. (2008). "Quantum information does exist." *Studies in History and Philosophy of Modern Physics*, **39**: 195-216.

Fair, D. (1979). "Causation and the flow of energy." *Erkenntnis*, **14**: 219-250.

Floridi, L. (2008). "A defense of informational structural realism." *Synthese*, **161**: 219-253.

Floridi, L. (2011). *The Philosophy of Information*. Oxford: Oxford University Press.

Floridi, L. (2016). "Semantic conceptions of information." In E. N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy,* URL = <http://plato.stanford.edu/archives/fall2016/entries

/information-semantic/>.

Frisch, M. (2014). *Causal Reasoning in Physics*. Cambridge: Cambridge University Press.

Grice, H. P. (1957). "Meaning." *The Philosophical Review*, **66**: 377-388.

Grice, H. P. (1989). *Studies in the Way of Words.* Cambridge MA: Harvard University Press.

Hughes, R. I. G. (1989). *The Structure and Interpretation of Quantum Mechanics*. Cambridge MA: Harvard University Press.

Hume, D. (2000) [1746]. *Enquiry Concerning Human Understanding*. Oxford: Oxford University Press.

Jozsa, R. (1998). "Quantum information and its properties." Pp. 49-75, in H.-K. Lo, S. Popescu and T. Spiller (eds.), *Introduction to Quantum Computation and Information*. Singapore: World Scientific.

Khinchin, A. (1957). *Mathematical Foundations of Information Theory*. New York: Dover.

Kolmogorov, A. (1965). "Three approaches to the quantitative definition of information." *Problems of Information Transmission*, **1**: 4-7.

Kolmogorov, A. (1968). "Logical basis for information theory and probability theory." *Transactions on Information Theory*, **14**: 662-664.

Korta, K. and Perry, J. (2015). "Pragmatics." In E. N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy*, URL = <http://plato.stanford.edu/archives/ win2015/entries/pragmatics/>.

Ladyman, J. and Ross, D. (2007). *Every Thing Must Go*. Oxford: Oxford University Press.

Landauer, R. (1991). "Information is physical." *Physics Today*, **44**: 23-29.

Landauer, R. (1996). "The physical nature of information." *Physics Letters A*, **217**: 188-193.

Lewis, D. (1973). "Causation." *Journal of Philosophy*, **70**: 556-567.

Lombardi, O. (2004). "What is information?" *Foundations of Science*, **9**: 105-134.

Lombardi, O., Fortin, F., and Vanni, L. (2015). "A pluralist view about information." *Philosophy of Science*, **82**: 1248-1259.

Lombardi, O., Holik, F., and Vanni, L. (2016). "What is Shannon information?" *Synthese*, **193**: 1983-2012.

McKay, I. P. (2010). "Why theories of causality need production: an information transmission account." *Philosophy and Technology*, **24**: 95-114.

Menzies, P. (2004). "Difference-making in context." Pp. 139-180, in J. Collins, N. Hall, and L. A. Paul (eds.), *Causation and Counterfactuals*. Cambridge, MA: The MIT Press.

Menzies, P. and Price, H. (1993). "Causation as a secondary quality." *British Journal for the Philosophy of Science*, **44**: 187-203.

Nielsen, M. and Chuang, I. (2010). *Quantum Computation and Quantum Information*. Cambridge: Cambridge University Press.

Pearl, J. (2009). *Causality: Models, Reasoning and Inference*. Cambridge: Cambridge University Press.

Penrose, R. (1998). "Quantum computation, entanglement and state reduction." *Philosophical Transactions of the Royal Society of London A*, **356**: 1927-1939.

Price, H. (1991). "Agency and probabilistic causality." *British Journal for the Philosophy of Science*, **42**: 157-176.

Reza, F. (1961). *Introduction to Information Theory*. New York: McGraw-Hill.

Rovelli, C. (1996). "Relational quantum mechanics." *International Journal of Theoretical Physics*, **35**: 1637-1678.

Russell, B. (1912). "On the notion of cause." *Proceedings of the Aristotelian Society*, **13**: 1-26.

Shannon, C. (1948). "The mathematical theory of communication." *Bell System Technical Journal*, **27**: 379-423.

Shannon, C. (1993). *Collected Papers*, N. Sloane and A. Wyner (eds.). New York: IEEE Press.

Solomonoff, R. (1964). "A formal theory of inductive inference." *Information and Control*, **7**: 1-22, 224-254.

Timpson, C. (2004). *Quantum Information Theory and the Foundations of Quantum Mechanics*. PhD diss., University of Oxford (quant-ph/0412063).

Timpson, C. (2006). "The grammar of teleportation." *The British Journal for the Philosophy of Science*, **57**: 587-621.

Timpson, C. (2013). Quantum Information Theory and the Foundations of Quantum Mechanics.

Oxford: Oxford University Press.

Von Wright, G. (1971). *Explanation and Understanding*. Ithaca: Cornell University Press.

Wetzel, L. (2008), *Types and Tokens: An Essay on Universals*. Cambridge, MA: The MIT Press.

Woodward, J. (2003). *Making Things Happen: A Theory of Causal Explanation*. Oxford: Oxford University Press.

Woodward, J. (2007). “Causation with a human face.” Pp. 66-105, in H. Price and R. Corry (eds.), *Causation, Physics, and the Constitution of Reality: Russell's Republic Revisited*. Oxford: Oxford University Press.

Woodward, J. (2013). “Causation and manipulability.” In E. N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy.* URL = <http://plato.stanford.edu/archives/win2013/entries/causation-mani/>.

Yeung, R. W. (2002). *A First Course in Information Theory*. New York: Springer.

Highlights

No communication without manipulation: a causal-deflationary view of information

- A causal-deflationary account of information in communicational contexts is proposed
- To transfer information is an asymmetric phenomenon involving causal notions: the destination system must be able to be *causally* manipulated by intervening on the source for successful communication.
- Our causal-deflationary account leads to a sharper and stronger concept of information in the communicational context, which is able to cope with tricky and anti-intuitive situations more naturally.