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Information Theory: Critical Analysis and Theory Construction

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Abstract

This paper covers a review of theory construction, a critical analysis of prior 'information theory', and an attempt in information theory construction. The outcome includes a theoretical statement and supporting propositions.

Keywords: information, information theory, theory construction

1. Introduction

We understand information implicitly. We understand its relation with data and knowledge. Yet information is still an elusive term simply because there is few if any clear definition. Information is usually defined in terms of data and sometimes in terms of knowledge. Description of relations between concepts/constructs is fine. However, definition between concepts/constructs in terms of each other becomes a logical fallacy (Liew, 2007). There is yet a widely accepted definition of information. This begs the question whether information theory is possible if the main construct is elusive and equivocal. Nevertheless, many research studies have given clues to what it is and how it transforms.

In the literature there is a Shannon information theory that pertains to statistics and communication issues rather than explicating information as the main issue (Al-Fedaghi, 2012; Tsvetkov, 2014). There is a gap between research and the understanding of information. Therefore, there is a need to develop a comprehensible and comprehensive theory of information since information has major impact on all concerned be it individuals, organizations, governments, and/or countries. This paper is structured in three main sections namely literature review with two parts, critical analysis, and theory construction.

2. Literature Review: Theory Construction

Bacharach (1989) stipulates a theory as a "statement of relations among concepts within a set of boundary assumptions and constraints", and its purpose is in twofold: "to organize (parsimoniously) and to communicate (clearly)". In other words, theory can be defined as "statement of relationships between units observed or approximated in the empirical world". Approximated units are referred as constructs that cannot be observed directly, while observed units are variables, which can be operationalized empirically by measurement. The primary goal of a theory is to answer the questions of what, how, when, why, and even so-what. (Bacharach, 1989; Whetten, 1989) Theory is about answering the queries of why and explicating the connections among phenomena why they occur. Theory emphasizes the nature of the causal relationships, examines the underlying process, and interprets the systematic reasons for occurrence or nonoccurrence. A good theory explains, predicts and delights. (Sutton & Staw, 1995; Weick, 1995)

In addition, a theory is constructed such that it is possible for empirical refutation also known as "Falsifiability". This is based on the common notion that theory cannot be proven but only disproven (Bacharach, 1989, *cf.* Nagel, 1961; Popper, 1959). There are two falsifiability examinations of the theoretical relationships; logical adequacy and empirical adequacy. Logical adequacy is the implicit and/or explicit logic embedded in the propositions and hypotheses that are capable of being disconfirmed. First, they should be non-tautological. Second the nature of the causal relationship between antecedent and consequence must be specified clearly. Empirical adequacy refers to propositions and hypotheses operationalization must be subject to disconfirmation, i.e. there must be more than one object of analysis, and/or object of analysis must exist at more than one point in time. (Bacharach, 1989)

Usefulness of the theory is the connection between theory and research in the form of explanation and prediction (Bacharach, 1989; *cf*. Bierstedt, 1959). Explanatory properties of a theory are in threefold: 1) clear specification of assumptions with regard to object of analysis; 2) clear specification of assumptions with regard to deterministic relations between antecedent and consequence; and 3) the scope and parsimony of the propositions. Predictive adequacy comes in two forms: probabilistic and theory based. Probabilistic predications are based on universal laws of probability, while theory-based predictions are grounded in propositions and deduced hypotheses. (Bacharach, 1989)

According to Whetten (1989), a complete theory should consist four essential elements; what, how, why, and who-where-when. 'What' refers to the factors (concepts, constructs, variables) considered as part of the explanation of the phenomenon in question, and it has to be well defined. 'How' refers as to how these factors relate usually shown in diagrams with arrows/boxes to depict causality. 'Why' refers to the underlying social, economic, or psychological rationale of the connecting factors and the causal relationships. "Who-where-when' refers to the conditions and limitations on the propositions generated from the theory (Sutton & Staw, 1995; Whetten, 1989). "A theory may be viewed as a system of constructs and variables in which the constructs are related to each other by propositions, and the variables are related to each other by hypotheses." (Bacharach, 1989)

> *Theory enlightens us by "clearing away conventional notions to make room for artful and exciting insights."* (DiMaggio, 1995)

3. Literature Review: Information Theory

"In 1948, Claude Shannon, a young engineer and mathematician working at the Bell Telephone Laboratories, published 'A Mathematical Theory of Communication,' a seminal paper that marked the birth of information theory. In that paper, Shannon defined what the once fuzzy concept of "information" meant for communication engineers and proposed a precise way to quantify it in his theory, the fundamental unit of information is the bit" (Guizzo, 2003). "Shannon provides a model whereby an information source selects a desired message, out of a set of possible messages, (which) is then formed into a signal. The signal is sent over the communication channel to a receiver, which then transforms the signal back to a message that is relayed to its destination" (Shannon & Weaver, 1949/1963, p.7; *cf*. Cornelius, 2002).

Shannon's "theory of information" is essentially mathematical theory of communication (Ahammad, et. al., 2004; Al-Fedaghi, 2012; Cornelius, 2002; Krippendorff, 2009). By Tsvetkov's (2014) account, it should be called a "statistical information theory". Shannon's "information theory… is a branch of the mathematical theory of probability and statistics." (Kullback, 1997)

There are no other versions of "information theory" or "theory of Information". However, in the literature, there are many articles in describing information and its relationship with data and knowledge, i.e., Bellinger, Castro & Mills (2004), Bernstein (2009), Buckland (1991), Hjørland (2007, 2009), Liew (2007, 2013), Ma (2007, 2012), Madden (2000). A comprehensible and comprehensive information theory does not exist as yet.

4. Critical Analysis

Concepts describing Shannon's "Information Theory" include "entropy", "uncertainty", "imprecise probabilities", "fuzzy", "information-based uncertainty" and "uncertainty-based information" (Cover, 1999; Klir, 2006). These are descriptors of statistical and mathematical concepts, not information per se. Shannon's "Information Theory" is fundamentally an algorithmic concept of information/communication. This phenomenon is a misnomer or worse a misconception of information and the theory of information. The information industry is void of a proper theory of information for many years if not decades.

In Shannon's "information theory", there was no definition of "information". How can a formalized theory lack the definition of its main construct?? Needed to be said with all due respect, Shannon's "information theory" is *not* a theory of information. There is no what, how, why, and who-when-where explication of information per se.

McKinney and Yoos (2010) survey of the term information within the information system literature, the extant of the IS literature failed to explicitly specify the meaning, or produce any theory on what information means, its scope or implications (Minger, 2018). Another survey by Furneau and Wade (2011) found similar results, the information literature incorporated information implicitly (Minger, 2018).

Majority of Information Theory content falls into two major categories. Aldridge, Johnson and Scarlett (2019), Brouty and Garcin (2023), Chanda et al., (2020), Gallistel, Craig and Shahan (2019), Hao et al., (2021), Kumar and Gupta (2020), Mourtzis et al., (2019), Perdigão et al., (2020), Ramos (2019), Rocchini et al., (2021), Sane, Fox-Kemper and Ullman (2023), Tschannerl et al., (2019), Zu et al., (2023) subscribe to Shannon's "Information

Theory" of entropy and communication; Enßlin (2019), Foley (2020), Hirche, Rouzé and Franca (2023), Radicchi et al., (2020), Stout (2021), Weijs and Ruddell (2020), Yu et al., (2020) subscribe to "Information Theory" of entropy, statistics and probability analysis; Merker, Williford and Rudrauf (2022), Mørch (2019), Pautz (2019) subscribe to "Integrated Information Theory" of consciousness which is a 'fundamental theory of consciousness' (quoted in Zimmer, 2010); IIT is primarily a theory of the 'level' or 'amount' of consciousness in a system; And Dayan (2023) subscribes to metacognitive analysis of the mind. Albeit the name Information Theory, the locus of analysis is not on information per se, nor the antecedent and consequence of information.

5. Information Theory Construction

5.1 The What

Information is meaning *per se* (Liew, 2007, 2013; Zins, 2007). The antecedent or source of all information is activities, events and situations (including objects, people, time and space) Activities, events, and situations have potential impact or effect on us, and thus they mean something to us (Liew, 2007). In other words, information allows us the understanding and interpretation of what is/was happening and further implication of what will be happening or possible future. We understand what it means (what is being informed).

5.2 The How

Activities, events, and situations (AES) generate information. Information has two main pathways; captured or recorded as data, or observed or perceived by human subjects. Otherwise, it becomes oblivious. There are two other secondary pathways; human subjects communicating and presenting (what was observed/perceived), or reconstruction of information through data analysis and compilation. There are two process cycles; information-data, and information-knowledge. (Diagram 1)

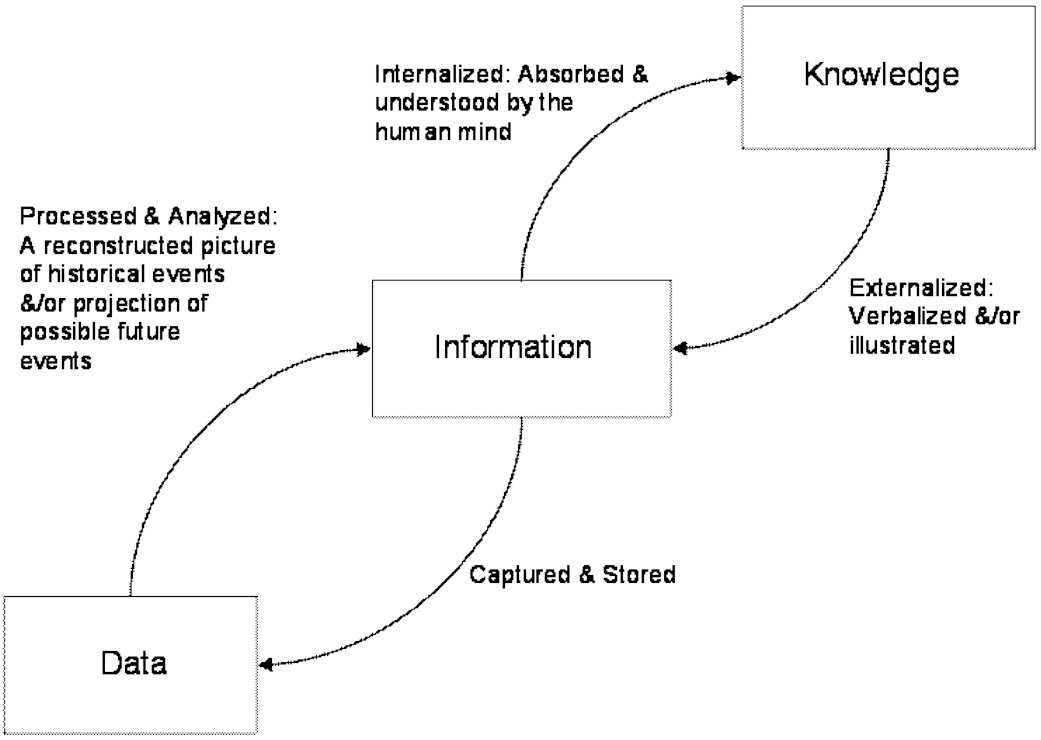

Diagram 1 (Liew, 2007)

5.3 The Why

Why do we need/want information? It is for the purpose of decision making and problem solving simply because AES has impact or potential effect on us. Information is therefore the antecedent of decision making and problem solving. The consequence of decision making and problem solving is the neutralization of negative impact and/or realization of opportunity.

5.4 Who-when-where

The intended recipients of information are decision makers and problem solvers (which is essentially everyone). Human decision making and problem solving are omnipresent (anytime) and ubiquitous (everywhere). This sets up the conditions of information theory as a generalized theory of information.

5.5 So-what

In the history of human progress, decision making and problem solving are the foundation of economic and social advancement. Information and its usage is a quintessential part of this progress. A better understanding of information and information theory would therefore promote greater effectiveness and efficiency of its usage.

5.6 Theoretical Statement

Information generated by activities, events, and situations (AES) feeds the decision making and problem making process for the purpose of neutralizing negative impact and/or realizing opportunity

5.7 Propositions

Proposition 1:	Semantics of Information is meaning. Data is the recorded representation of Information
Proposition 2:	Mechanics of information theory
Proposition 2.1:	AES generate information. Information is the construct; the variable (measurable) is data which is the representation of information.
Proposition 2.2:	Data to information is a reconstruction of AES, and/or projection of future AES
Proposition 2.3:	Information to data is recording of AES
Proposition 2.4:	Information to knowledge is internalization of a subject matter via observation and learning.
Proposition 2.5:	Knowledge to information is externalization of a subject matter via illustration and communication.

Proposition 3: Information is the input of decision making and problem solving.

The output variable is decision and solution which is also data (text, numbers, action plan etc.) Negative impact and opportunity can be operationalized with variables measuring economic loses or gains, or abstract losses/gains in expected value

5.8 Assumptions

1. Information assessment is based on human needs and wants to know
2. Human interpretation of information is pragmatic

5.9 Limitations

Analysis of written document is under the English language.

6. Conclusion

This paper has reviewed what theory construction should be, shown what prior "information theory" isn't, and what information theory should be. Albeit information is omnipresent and ubiquitous, even polysemous, the common ground is its usage in decision making and problem solving in any field, discipline or organization. Future research studies would have to verify or disprove this theory.

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