Data, Science and Society

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The foundations of experience (since we absolutely must get down to this) have been non-existent or very weak; nor has a collection or store of particulars yet been sought or made, able or in any way adequate, either in number, kind or certainty, to inform the intellect. [...] Natural history contains nothing that has been researched in the proper ways, nothing verified, nothing counted, nothing weighed, nothing measured.

Francis Bacon, 1620.¹

The word "data" comes from the plural of the Latin word datum, meaning something given.² The first uses of the word in a scientific context can be traced back to the mid 17th century, where the quote by Bacon suggests it arose as a means to try to conceptualize scientific research. In modern-day usage, the word refers to collections of measurements and factual information that form a basis for research, reasoning, supporting evidence, etc.³ With the advent of computers in the mid 20th century, a new meaning was added to this traditional scientific sense. It indicates the basic abstract entities that the new machines deal with ("transmittable and storable computer information", 1946). Both, the scientific and computing senses remained confined to rather technical communities until recently. For example, the word "data" did not capture enough attention from Raymond Williams to merit its inclusion in Keywords in 1983.⁴

The popularization of the word "data" in the news headlines, in magazine covers and in any report seeking to be considered scientifically grounded, is quite recent. Two metaphors are responsible for this miracle: first, the notion of "data deluge" and then the noun "big data".

The notion of data deluge is powerful: an overflow of society and humans with data. Despite its strong call to our daily experience, the notion is highly misleading. First, it suggests something produced by an other, traditionally by a punishing God, or by natural powers external to our command. Second, it makes current levels of data a catastrophe, surrounding data with a negative connotation. In summary, it presents data as something that we can only react to, or even defend ourselves from.

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¹ F. Bacon, The New Organon. Edit. L. Jardine, M. Silverthorne. Cambridge Univ. Press, 2000. Aphorism XCVIII, p. 80.

² Despite that data is highly countable, in what follows, I will consider "data" as non-countable noun, like water, love, information, oil. Hence I will treat it as singular.

³ D. Rosenberg. Data Before the Fact. American Historical Association, 2012.

⁴ R. Williams. Keywords, 1983.

The notion of big data is less deceiving. It avoids the explicit negative connotation and highlights a main feature of the phenomenon: the size. People in computing coined the term in the early nineties⁵, but the hype in bussiness (that popularized it) is more recent. In science and reaserch the term began to be widely adopted only in the 21st century.⁶ My concern with this notion is that it still represents the phenomenon as an external and unapproachable object. In fact, many people speak (and think) of "big data" as an obscure and phantasmal object, far from the control of mankind, haunting modern society. It is like a living nebula growing around us waiting to be tamed and ready to run over us if not taken seriously.

1 Torrents of Data

Let us retain the essential fact: there is an enormous amount of data around. At this point one can ask why this hype over data *now*. Historically, there have been several tsunamis overflowing the semantic and symbolic capacities of the human. The adoption of writing and of media to preserve it without doubt shook and transformed contemporary ways of approaching information. Later the printing press must have produced a similar upheaval among the literate population. More recently, magazines, newspapers and pervasive technology of printing, plus the radio and television media overhelmed people with information. In the 1930's, the Spanish thinker José Ortega y Gasset, in a speech to the International Congress of Libraries and Bibliography, spoke of the "raging book" and expressed his fears as follows:

"There are already too many books. Even when we drastically reduce the number of subjects to which man must direct his attention, the quantity of books that he must absorb is so enormous that it exceeds the limits of his time and his capacity of assimilation. [...] The culture which has liberated man from the primitive forest now thrusts him anew into the midst of a forest of books no less inextricable and stifling." And concluded: "Here then is the drama: the book is indispensable at this stage in history, but the book is in danger because it has become a danger for man."

The book –according to Ortega– became a danger for man. We hear similar remarks about data today. What is going on beneath the surface? The problem then and today can be stated, paraphrasing a well known text about social change, as follows: At a certain stage of development, the material forces of society began producing more symbolic material than the one existing social relations can digest. From forms of development of the culture these relations turn into their fetters. Then begins an era of information upheaval. The problem we face today is that capture, production and digestion of data surpasses by far the social and human capabilities to manage and process it.

Let us develop this idea. The data that worries us are not billions of units of understandable data (what scared Ortega), but the not understandability of the unit itself. Let us explain. There are no unreadable books. Each of them was designed (written) to the be read by a human (even In Search of the Lost Time). The obstacle Ortega was pointing to was the almost infinite number of books. The main problem was the quantity (and his solution functioned accordingly: to limit the

 $^{^5}$ See https://bits.blogs.nytimes.com/2013/02/01/the-origins-of-big-data-an-etymological-detective-story/

⁶ Editorial of Nature special issue about Big data (2008) "Researchers need to adapt their institutions and practices in response to torrents of new data".

⁷ José Ortega y Gasset. Misión del Bibliotecario. 1935. The Mission of the Librarian. Translated by J. Lewis and R. Carpenter. The Antioch Review, Vol. 21, No. 2, 1961, pp. 133-154.

$$\label{eq:human scale} \begin{cases} & \text{Byte B} & \sim 10^0 & \text{a character} \\ & \text{Kilo KB} & \sim 10^3 & \text{written text} \\ & \text{Mega MB} & \sim 10^6 & \text{image, music} \\ & \text{Giga GB} & \sim 10^9 & \text{movies} \end{cases}$$

$$\text{beyond human} \begin{cases} & \text{Tera TB} & \sim 10^{12} & \text{U.S. Congress Library} \\ & \text{Peta PB} & \sim 10^{15} & \text{Large data center} \\ & \text{Exa EB} & \sim 10^{18} & \text{All words ever spoken} \\ & \text{Zetta ZB} & \sim 10^{21} & \text{Amount of global data} \end{cases}$$

Table 1: Data sizes and human-scale

production of books). On the other hand, the problem with data is that the unit itself (a dataset) is not intelligible by a human, and worst, there are almost infinitely many datasets. The problem is both quality and quantity.

A metaphor from physics could help at this stage. Traditional mechanics is a human-scale discipline in the sense that allows the direct participation of people. A bicycle is an artifact we can understand, repair, transform almost entirely by ourselves. Chemistry first and then atomic physics crossed the barrier of the human manageable objects, a barrier beyond which the built-in senses of the human do not help anymore. Today the advances in new technological media (computer power and memory, networks, sensors, communication, etc.) has dramatically increased the capacity of capturing data (sensors, telescopes, Web, etc.); of producing data (computers, games, media, LHC, etc.); of storing data (memory, storage media, cloud, etc); of analyzing data (statistical techniques, neural networks, (deep) learning, etc.). In one sentence: the limit we are surpassing today is that of the human capabilities to understand and manipulate these vast new world of symbolic objects.⁸

Despite Ortega's complaints, until very recently we humans could approach all symbolic objects around us: texts, photographs, music, movies. But today this symbolic world is growing so fast that escapes our "natural" human and societal capacities to handle it, and thus we feel that an obscure and daunting, fundamentally unintelligible, (parallel) world is growing in front of our eyes. Let us clarify. It is not that this symbolic world did not exist before. It existed and was vast, but essentially volatile. The essential novelty is that it is being increasingly materialized in the form of (digital) data and that ICT technologies have made us become aware of its vastness. (See some numbers in table 1.) My hypothesis is that these objective and subjective phenomena have made obsolete the conceptual models used to deal with the symbolic world. Among the main challenges is the notion of scale.⁹

⁸ Hans Moravec. When will computer hardware match the human brain? Journal of Evolution and Technology. 1998. Vol. 1. http://www.jetpress.org/volume1/moravec.htm

⁹ Clark C. Gibson, Elinor Ostrom, T.K. Ahn. The concept of scale and the human dimensions of global change: a survey. *Ecological Economics* 32 (2000) 217-239.

2 The Notion of Data

The audience —mostly of librarians, those rare intellectuals whose life's objective is to contribute to other people's growth—is familiar with the subtle relations existing among the notions of knowledge and information. Let us assume for now the widely accepted premise that data is in some sense the starting point, constitutes a basic building block, of information and knowledge.¹⁰ On these lines, let us present some facets and assumptions relevant for our understanding of this concept.

- 1. At the most basic and abstract level, data is a distinction, *i.e.*, a sign of a lack of uniformity in the world out there. As Luciano Floridi states: "As "fractures in the fabric of being" they can only be posited as an external anchor of our information, [...] are never accessed or elaborated independently of a level of abstraction." Caroline Haythornthwaite points to the same from another point of view: "Datum is [the] smallest collectable unit associated with a phenomenon. Normally, data occur in collections that are collected in order to monitor a process, assess a situation, and/or otherwise gain a referent on a phenomenon." ¹² In summary, data is the most basic layer in the symbolic world. Data has no meaning by itself, but is the source of meaning.
- 2. By data, we will mean materialized (digitally recorded) data, that is, data once it has been frozen into material (digital) symbols. In this regard data, in the sense we are treating it in these notes, is part of the "objective" world. Data is thus a material collection of symbols. This is the spirit of the following entries in the definition of data: "information in numerical form that can be digitally transmitted or processed" (Merriam-Webster) and "The quantities, characters, or symbols on which operations are performed by a computer, which may be stored and transmitted in the form of electrical signals and recorded on magnetic, optical, or mechanical recording media." (Oxford). In summary, despite its ontological ambiguity between the material and the intangible, data is material.
- 3. The distinctions that define data assume an implicit context. This network of meanings is not stated explicitly, that is, not specified in the data itself. This allows manifold interpretations of the same data from different points of view, to further explore new dimensions, etc. A good example is a photograph. With high probability, the photographer took it with some agenda in mind. But future generations could use it to "view" dimensions that were not present in the original focus of the original photographer. Some contexts are usually explicitly included as metatada, that is, additional data that give information or signal relations in the bulk data. In summary, data has meaning, though not always explicit meaning. Although collected/constructed with some objective in mind, it allows diverse interpretations and can support manifold thesis.

Data is the starting point for our discussion. Our task is not to clarify the ontological status of data, but to understand its properties, its "mode of combination", and hopefully to get a conceptual

¹⁰ Ch. Zins. Conceptual approaches for defining data, information, and knowledge. Journal of the American Society for Information Science and Technology 58, 2007. pp. 479-493

L. Floridi, Semantic Conceptions of Information. SEP, version Wed Jan 7, 2015 https://plato.stanford.edu/entries/information-semantic/

¹² C. Haythornthwaite. In Ch. Zinns, op. cit., p. 483.

¹³ It is important to distinguish the intrinsic metadata, what in the database field is called a *schema* (describing existing types, relationships among fields, etc. in a dataset), from metadata describing whole datasets. Example of the latter are the 15 classical properties of the Dublin Core Metadata Element Set (version 1.1): contributor, coverage, creator, date, description, format, identifier, language, publisher, relation, rights, source, subject, title, and type.

model for it. That is, for us, as data guardians, curators, facilitators, data is just something given, as the original Latin meaning. Our concern at this stage is not the possible semantics that could be distilled from the data, but the data as "material" element. Using the counterpoint between worlds of bits and atoms popularized by Nicholas Negroponte in *Being Digital*, ¹⁴ we work in the world of bits, a world as material as the one of atoms, but with strongly different social significance as we will see.

Taking advantage of the bit-atom opposition, another metaphor could help shedding light on the relations between these two worlds:

$$\frac{\mathrm{Data}}{\mathrm{Virtual~World}} = \frac{\mathrm{Atoms}}{\mathrm{Material~world}}$$

Pushing forward the association of ideas, the science of data would be the chemistry of the virtual world. The sciences of information and knowledge work with this material, but at a different level of grouping and abstraction.

3 Research and scientific Data

The notion of research data, under terms like experience, facts, observation, evidence, etc. has a long history. "Observation" in its scientific sense is mentioned by Aristotle; Bacon advocated its relevance for research; and the awareness of the subleties of its connection to knowledge date from the beginning of the 20th century.¹⁵ Nevertheless, is it only at the turn of the 21st century that data began to be thought of as a driver of science. Turing award recipient Jim Gray wrote in 2007:

"Originally, there was just experimental science, and then there was theoretical science, with Kepler's Laws, Newton's Laws of Motion, Maxwell's equations, and so on. Then, for many problems, the theoretical models grew too complicated to solve analytically, and people had to start simulating. These simulations have carried us through much of the last half of the last millennium. At this point, these simulations are generating a whole lot of data, along with a huge increase in data from the experimental sciences. [...] The world of science has changed, and there is no question about this." ¹⁶

This change driven by the "material forces of society" is producing social changes, in particular giving a prominent value to scientific data. The argument works as follows.

Since the industrial revolution there was awareness of the expanding role of (scientific) knowledge in the economy, but only recently it has become a central player of it as the Organization for Economic Co-operation and Development recognizes:

"The term "knowledge-based economy" results from a fuller recognition of the role of knowledge and technology in economic growth. Knowledge, as embodied in human beings (as "human capital") and in technology, has always been central to economic development. But only over the last few years has its relative importance been recognised,

 $^{^{14}}$ N. Negroponte. Being Digital. Vintage Books, New York, 1996.

James Bogen, Theory and Observation in Science. SEP, version Mar 28, 2017. https://plato.stanford.edu/entries/science-theory-observation/

¹⁶ Jim Gray on eScience: A Transformed Scientific Method. (Based on the transcript of a talk given by Jim Gray to the NRC-CSTB1 in Mountain View, CA, on January 11, 2007.) In: T. Hey, S. Tansley, K. Tolle. The Fourth Paradigm. Data-Intensive Scientific Discovery. Microsoft Research, 2009.

just as that importance is growing. The OECD economies are more strongly dependent on the production, distribution and use of knowledge than ever before." ¹⁷

From this statement and the premise stated above by Jim Gray ("science today is heavily based on data"), the conclusion follows: data is the raw element of this new process of production. A more allegorical version of this statement is: "data has become the new oil".¹⁸

As data is playing an essential role in the economy, its production process is being under pressure for efficiency. Thus division of labor is affecting its cycle —data capture; data curation; data analysis; data visualization—that traditionally was done by the same person or team. (Tycho Brahe / Copernicus are an exception). The scientist and his collaborators designed the experiment or the process of data collection (Von Humbolt, Darwin, Mendel, Pasteur, etc.). In particular, today there is an increasing tendency to separate the uses and the production/collection of data. In this way data is acquiring a certain degree of autonomy.

Another relevant facet of scientific data is the old, but ongoing debate, about the epistemic status of observation versus experimentation. The first, rather direct and implicitly without touching, without asking, the object. The second is a product of direct manipulation of the object to extract what is needed. Bogen gives a good example: "To look at a berry on a vine and attend to its color and shape would be to observe it. To extract its juice and apply reagents to test for the presence of copper compounds would be to perform an experiment." The distinction, if there is one, is subtle. One can state it in computational terms as the question: Static or Dynamic data? Bulk Data or API? The discussion is relevant not only for how to collect or produce the data, but for how to store it and how to deliver it to final users. In fact we need both types of data. Today we can "expose" live data, in the form of an API, through cameras, from sensors, etc. This is becoming an increasingly relevant source of data. There is a growing interest in technologies devised to process them lively, *i.e.*, as a stream of data. Common examples are the value of currencies on the Web, Weather channels, live news, etc.

Last, but not least, we should call the attention to the blurring differences between "scientific" data and "common" data. Data comes in many forms and sources. One speaks of scientific data as that collected systematically in the framework of a scientific endeavor. Today, there are huge data companies outside what we would consider "scientific" projects or institutions, particularly at the social level (which are among the most noisy and popular data). Tweets, identities and behavior of users in social networks, social footprints of any kind, personal images and videos, etc., are among the most valuable data. It is becoming everyday more difficult to trace a clear divisory line between scientific and, say, non-scientific data. At the end, all data is collected with some purpose in mind (nobody would spend time, energy, resources to collect data that would not have some, although far off, goal.)

¹⁷ OECD. The Knowledge-based economy. OECD, Paris 1996.

¹⁸ Seems that Clive Humby was the first to coin this statement: "Data is just like crude. It's valuable, but if unrefined it cannot really be used. It has to be changed into gas, plastic, chemicals, etc. to create a valuable entity that drives profitable activity; so must data be broken down, analyzed for it to have value." http://ana.blogs.com/maestros/2006/11/data_is_the_new.html Since then, in Forbes, Fortune, Wired, etc. have appeared articles with this idea in the title.

¹⁹ J. Bogen. op. cit.

²⁰ J. Tauberer. August 2014. https://opengovdata.io/2014/bulk-data-an-api/ (API: Application Programmer Interface. For data, intuitively, an interface oriented to be used not by a human, but as source where applications can be pluged to automatically interact with or retrieve data.)

4 The Social Character of Data

We have learned that data is everywhere; that data is relevant; that it is valuable. Not surprisingly international organizations, governments, communities are devising ways to approach, and/or take advantage of, this new resource.

As we saw, data is a resource that is essential to the development of scientific knowledge, and as such, relevant to the understanding of us as humans, to the development of our societies, and to satisfy personal human needs. On the other hand, as a "new oil", that is, as an economic good, it is under the tension of economic categories.

A naive approach would treat data in a similar way as knowledge, a resource that looks at first sight as non-excludable and non-sustractable, as Joseph Stiglitz, then Chief economist of the World Bank, explained:

"A public good has two critical properties, non-rivalrous consumption—the consumption of one individual does not detract from that of another—and non-excludability—it is difficult if not impossible to exclude an individual from enjoying the good. [...] Knowledge is a global public good requiring public support at the global level.".²¹

We could change "knowledge" by data and obtain a program for data as a public good. It is, in fact, the program of several government and international agencies. For example, the World Bank's focus is to make data accesible to particulars in order to "allow policymakers and advocacy groups to make better-informed decisions and measure improvements more accurately." Along similar lines, OECD has a program for open access, defined in its *Principles of Access to Research Data* as follows: "Openness means access on equal terms for the international research community at the lowest possible cost, preferably at no more than the marginal cost of dissemination. Open access to research data from public funding should be easy, timely, user-friendly and preferably Internet-based." ²³ From these principles follow the transparency and interoperability policies for governments.

A good example of these initiatives in the scientific area is the U.S. *National Science Foundation*'s open data policy, stating that "agencies must adopt a presumption in favor of openness to the extent permitted by law and subject to privacy, confidentiality, security, or other valid restrictions." They define open data as follows:

"Open data are publicly available data structured in a way to be fully accessible and usable. This is important because data that is open, available, and accessible will help spur innovation and inform how agencies should evolve their programs to better meet the public's needs."

They state seven principles of consistency with open data, namely to be public, accessible, described, reusable, complete, timely and managed post release.

A different source for openness comes from the pressure of diverse communities known as "open data" movement. Their notion of open data is essentially taken from the "open source" and "open

²¹ J. Stiglitz, Knowledge as a Global Public Good. In: Global Public Goods: International Cooperation in the 21st Century, 1998.

World Bank Open Data Initiative. World Bank, 4/30/2010. data.worldbank.org

²³ OECD Principles and Guidelines for Access to Research Data from Public Funding. OECD, April 2007. p.15.

²⁴ Open Data at NSF. https://www.nsf.gov/data/

access" communities. The "translation" of these notions to the world of data bears the same issues and challenges (no less, no more) than in those fields. The *Open Data Handbook* ²⁵ defines it as follows: "Open data is data that can be freely used, re-used and redistributed by anyone –subject only, at most, to the requirement to attribute and sharealike." As we can see, there is here a more ample conception than that of World Bank, OECD and international organizations and governments, whose openness agendas are triggered mainly by economic concerns.

5 Final Remarks: Beyond Access

Despite the advances these policies about access bring, relevant issues for data remain open.

Most approaches used to address the notion of "open data" implicitly associate it to knowledge and/or information, whose main threat is effectively enclosure (in the form of patents and copyright). A key assumption in this analysis is that the "good" under the threat of enclosure is something ready to be consumed. Thus, the ultimate goal is access, that would allow people to consume that good. This premise holds for simple data, as spreadsheets, transparency data, etc., but does not hold for most data today, namely "big" data. Access in this case is just a first step in the data cycle (collection; curation; analysis; visualization). The resources needed to store and cure data, to analyze, and to finally visualize or use it, are tremendous. The challenge is the scale.

Here the framework of commons comes to the rescue. As Charlotte Hess and Elinor Ostrom state,

"the essential questions for any commons analysis are inevitably about equity, efficiency and sustainability. Equity refers to issues of just or equal appropriation from, and contribution to, the maintenance of a resource. Efficiency deals with optimal production, management and use of the resource. Sustainability looks at the oucomes over the long term." ²⁶

Due to the enormous sizes of data, to think about data as common implies including the whole cycle of data as commons. Data is a resource shared (and produced) by groups of people. On its intangible face, is clearly non-excludable and non-rivalrous: sharing it is almost effortless; consuming it does not substract the possibility of others to do the same. The problem comes when we consider its material face. Here all the issues of a "material" commons surface, with its dilemmas of commodification or enclosure, pollution and degradation, and nonsustainability.

Data came to our societies to stay. And we already hear that data is the new oil. The allegory can be expanded to include the history of oil on earth: It warns us of the possible conflicts that the appropriation of this new resource could bring. It will depend on us, humans, to define what we want from this new oil and how we can use it to improve our lives and societies.

The discussion we should open today is how we would like to manage and govern this new good, including how it is generated, accessed, stored, curated, processed and delivered. The commons approach offers fresh insights to address these challenges.

What is Open Data? Open Data Handbook. http://opendatahandbook.org/guide/en/what-is-open-data/

²⁶ Ch. Hess, E. Ostrom (Ed.) Understanding Knowledge as a Commons From Theory to Practice. MIT Press 2006. Introduction, p. 6.