SCUOLA INTERNAZIONALE SUPERIORE DI STUDI AVANZATI

MASTER IN COMUNICAZIONE DELLA SCIENZA “FRANCO PRATTICO”

Visual abstracts to disseminate research on Twitter: A quantitative analysis

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Trieste. February, 2018.

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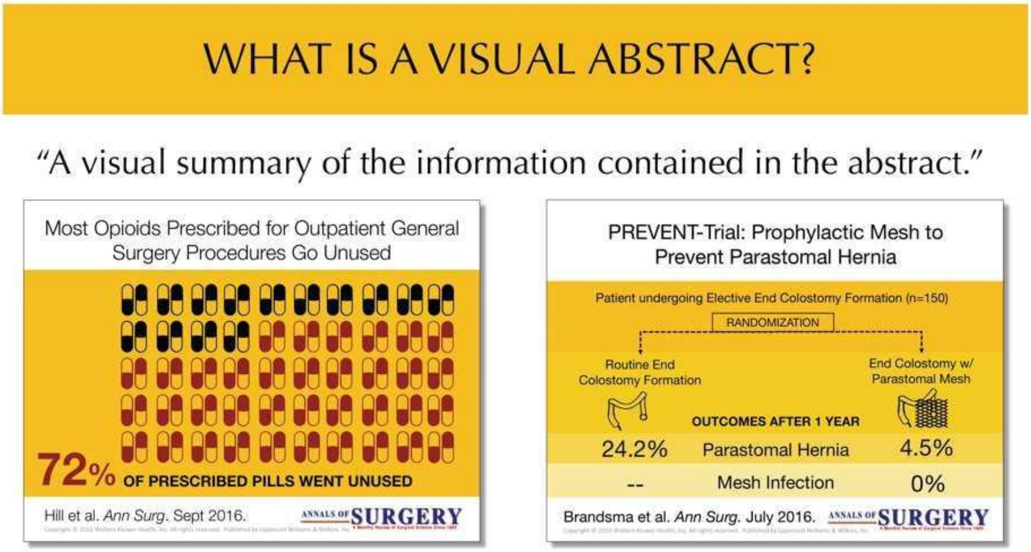
INTRODUCTION

The Web has indisputably changed the way researchers share information. Web-based scholarly communication allows to rapidly disseminate research findings, to reach a broader audience, to transversely connect different contents through hypertext linkages, to update and correct texts if needed, and to integrate multimedia materials. Moreover, it allows interactivity and real-time exchange between authors and readers.

Such features are even more evident in the context of the so-called Web 2.0, which involves user-generated content, data sharing, and collaborative efforts. The diffusion of social software and web-based applications has lead to a new use of the Web as a platform for generating, re-purposing and consuming scientific content. Social media brought additional advantages and challenges: they help to fulfill the demand for cheap, instant communication in a context of growing collaborative and interdisciplinary research, but they also, for example, add complexity in terms of quantification of the impact of scientific articles.

Nevertheless, researchers are now using social media platforms in every phase of the research lifecycle, from identifying opportunities to disseminating findings. In particular, Twitter, the microblogging platform that allows users to post/publish short messages up to 140 (now 280) characters, has emerged as a powerful tool in scholarly communication. Indeed, it connects researchers around the world (both within and outside one's research field), giving them the chance to communicate and discuss research findings with the rest of the scientific community, to provide and receive post-publication critiques, and to increase the reach and the impact of their work.

Recently, also scientific journals adopted social media, and Twitter in particular, to disseminate research findings published on their pages and websites. In the field of biomedical research, this led to the development of new strategies of dissemination. In July 2016 the journal *Annals of Surgery*, the world's most referenced surgery journal, introduced the visual abstracts. According to Andrew I. Ibrahim, Art Director of the journal, a visual abstract is "a visual summary of the information contained within an abstract. Similar to the text abstract of a research article, it is meant to convey the key findings of the article in a shorter format" (Ibrahim, 2016, p.3). Thus, visual abstracts are infographics that inform potential readers of the main contents of a scientific article, to help them decide if they want to proceed reading the entire article. They respond to some social media communication criteria (e.g., the use of visuals), so their use may also represent an attempt to make scientific contents accessible to a broader audience. The use of visual abstracts presents some advantages: for example, they improve dissemination, they create a scaffold for deeper engagement, and, as they are easily accessible, they can influence clinical practice. But the diffusion of visual abstracts is also associated with potential perils, such as oversimplification, exacerbation of biases, and poor quality.



Visual abstracts: definition and examples (Ibrahim, 2017).

The present thesis aims at investigating if, and how, the use of visual abstracts may be associated with potential threats to scholarly communication.

In the first chapter, I will introduce the main characteristics of scholarly communication from an historical and sociological point of view, describing the evolution of scientific articles and scientific journals from the 17th century to the advent of the web.

In the second chapter, I will describe scholarly communication and research dissemination on social media, and Twitter in particular, dwelling on how scientific journals are embracing these tools to disseminate their publications.

Finally, in the third chapter, I will report methods and results of a quantitative analysis of all visual abstracts published on Twitter by the accounts of scientific journals during the first year after the introduction of this tool. To understand where visual abstracts are positioned along the continuum between scholarly communication and social media communication/marketing criteria, graphic features, as well as informativeness and social media/web diffusion parameters, have been considered.

CHAPTER 1

The scholarly communication: Past, present, and future

1. The scholarly communication

In 2001 the Higher Education Funding Councils for England defined, for the purposes of the UK research assessment exercise, the term *scholarship* as “the creation, development and maintenance of the intellectual infrastructure of subjects and disciplines, in forms such as dictionaries, scholarly editions, catalogues and contributions to major research databases” (Higher Education Funding Councils, 2001, p. 8). This definition, however operational, appropriately describes scholarship as an inherently social process, whose end products must be publicly available information objects. Thus, scholarship is not an activity which can be undertaken in isolation, it necessarily involves communication (Halliday, 2001). As Borgman reported, “research in all fields is incomplete until it is validated through review processes and shared with others” (Borgman, 1990, p. 13).

However, different authors refer differently to the term *scholarly communication*.: Klink and McKim, for example, defined it as an interactive process in which scholarship is communicated, used and developed within a community (Klink and McKim, 1999); Borgman, instead, described it as “how scholars in any field use and disseminate information through formal and informal channels” (Borgman, 1990, p. 14). Other authors defined scholarly communication in terms of outputs, as articles published in scientific journals or similar formats (Alexander & Goodyear, 2000; Graham, 2000). Precisely, Graham divided the scholarly communication process into three stages: communication within informal networks, which includes personal relationships and private discussions; the initial public dissemination of research, through conferences and preprints; and finally, formal publication in scientific journals (Graham, 2000). This last stage, defined as *scholarly publication*, is particularly critical for science because it not only represents a strategy to disseminate knowledge claims, but also a methodology to define competence within the community, through the certification of competent peers.

The term scholarly publication typically refers to the release of scientific articles in peer-reviewed scientific journals and, in the context of electronic media, to all forms of online distribution of such documents (Kling & McKim, 1999; Borgman, 2000). In addition to peer-review, other characteristics are required to define a formal scientific publication; these are particularly relevant in the context of web-based communication, where the border between formal and informal is often blurred. It must be publicly available; the relevant community must be made aware of its existence; a system for long-term access and retrieval must be in place; it must not be changed; it must not be removed (unless legally unavoidable); it must be unambiguously identified; it must have a bibliographic record containing certain minimal information; archiving and long-term preservation must be provided for (Frankel et al., 2000). These recommendations are needed because, as Halliday reported: “Publication is the hard currency of science. It is the primary yardstick for establishing priority of discovery, making the status of a publication a critical factor in resolving priority disputes or intellectual property claims. Academic tenure and promotion decisions are based in large part on publication in peer reviewed journals or scholarly books” (Halliday, 2001, p. 116). Thus, assurances are needed of what counts as a legitimate publication. Several players are involved: authors, readers, staff and students of institutions, university management, research councils, funding bodies, government bodies, libraries, and publishers (Graham, 2000). So even if trustworthiness is primarily determined by the peer review process, it also necessarily depends on the reputation of the publisher, the reader's knowledge of the researcher, the reputation of the researcher's institution and, in case of a journal publication, of the journal itself (Halliday, 2001; Kling & McKim, 1999).

1.1. Scientific journals and articles

Scientific journals, usually specialized for different academic disciplines or subdisciplines, represent the most important means for disseminating research findings. The first independent scientific journal, the *Journal des Sçavans*, was published (“To make known experiments that might serve to explain natural phenomena”) in Paris, on behalf of the Académie des Sciences, in January of 1665. It was followed by the *Philosophical Transactions* of the Royal Society, in Britain, a few months later (Gross, Harmon, Reidy, 2002; Kronick, 1976). From that moment, there has been an increase in the number of scientific journals by 7% a year, doubling the total number of new journals every 10-15 years (de Solla Price, 1961). Between 1665 and the second half of the 20th century, about 100,000 new scientific journals have been launched **(Fig. 1**). Since many of them have obviously ceased to exist, the estimate today suggest that some 60,000 – 70,000 scientific journal are currently printed, publishing reports of original research, re-analyses of others' research, proposals of new but untested theories, reviews of the literature in a specific area, proposals of new but untested theories, or opinion pieces (Höök, 1999).

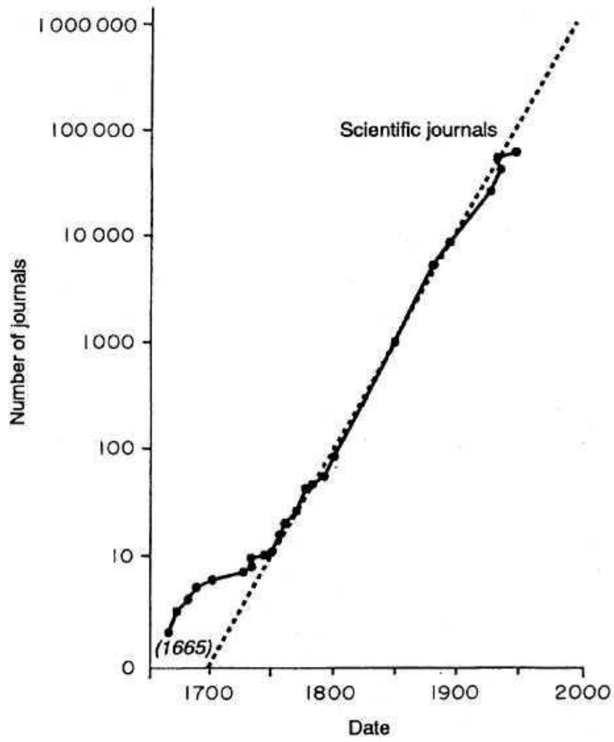


Fig. 1 Number of scientific journals started between 1665 and 1961 (de Solla Price, 1961).

As reported by Gross, Harmon, and Reidy in their book *Communicating Science: The scientific article from the 17th century to the present*, this remarkable fecundity is, especially in the 20th century, mainly due to a progressive professionalization and hyperspecialization of science (Gross, Harmon, Reidy, 2002; Menard, 1971).

But what distinguishes a scientific journal from a non-scientific one? The first one can be defined as a publication that contains original articles written by scientists and evaluated for technical and scientific quality by experts in the same field. As previously said, this process of evaluation, the so-called peer review, is one of the main characteristics of scholarly publishing. Once a given research paper is delivered to an editor, two or more experts submit critiques to the publisher regarding the strengths and weaknesses of the article, together with editorial suggestions and recommendations. These experts are not financially compensated and are selected based on their scientific expertise, research area, and lack conflict of interests or bias toward the authors. The editor then reads the manuscript and the reviewers' comments and decides if the paper should be rejected, revised and resubmitted for further review, or accepted.

Notably, as publications on scientific journals often function as a measure of scientists' competence and of the relevance of their knowledge claims, bibliometric methods are frequently used to provide quantitative analysis of academic literature. The most used parameter is the so-called impact factor, a measure reflecting the yearly average number of citations to recent articles published in a given journal, often used as a proxy for the relative importance of that journal within its field. However, as reported by its inventor Eugene Garfield, the term impact factor has then gradually evolved to describe both journal and author impact: "This ambiguity often causes problems. It is one thing to use impact factors to compare journals and quite another to use them to compare authors. Journal impact factors generally involve relatively large populations of articles and citations. Individual authors, on average, produce much smaller numbers of articles although some are phenomenal" (Garfield, 2005, p. 4). Other indexes are commonly used today to measure the impact of scientific articles or journals. There is the h-index, an author-level metric that measures both the productivity and the impact of a scientist's publications; the acknowledgement index, which quantify the impact of acknowledgement in scientific literature; and citation indexes (e.g., Science Citation Index, Google Scholar Citation Index, Elsevier's Scopus), which allow readers to easily establish which later documents cite earlier documents. Recently, non-traditional indexes have been introduced, such as Altmetrics: a measurement derived from the social web which also covers aspects as article views, downloads, or mentions in social media, blogs and news media (Thelwall et al., 2013).

Returning to 1665, the main reason why the publication of the first issues of the French *Journal des Sçavans* and the British *Philosophical Transactions* was critical for the evolution of science is the birth of the scientific article. Gross, Harmon, and Reidy so describe the relevance of this event: "This birth was key in the then-fledging enterprise of science. It permitted the relatively rapid and accurate transmittal of new discoveries and ideas from one researcher to a community of researchers – who could then propagate, refute, accept, ignore, or extend the original claims. Emerging from letters and essays and competing with books, this new medium developed a style and format that, eventually, would make it the preferred mode of presentation and debate for new claims of scientific knowledge" (Gross, Harmon, Reidy, 2002, Preface). Over the centuries the scientific article has become the canonical form for the communication of original research results and represents, for this reason, an important cultural and intellectual phenomenon. It also is a developing vehicle for communicating the conceptual system of science and, in the case of its argumentative characteristics, a developing mean for creating that system. It is hence essential to summarize the evolution of scientific articles from 17th and 21st century. To do so, I have considered changes in style, presentation, and argumentation.

1.2. The evolution of scientific articles

Gross, Harmon, and Reidy describe this evolution through the conceptual framework of selection theory: "The communicative phenotype of the article is constituted by three suites of characters: style, presentation, and argument. Over time, these characters vary, and through their genotypes (e.g. to create arguments, to transform these arguments into sentences and paragraphs, to order the sentences and paragraphs according to well-recognized organizational constraints), these variants selectively reproduce as a consequence of the varying needs of the different scientific disciplines, the article's niche" (Gross, Harmon, Reidy, 2002, p. 219). Importantly, as biological organisms, scientific articles would have not evolved in the sense of becoming better (or worse), but in the sense of changing to cope with the needs of an ever more complex communicative environment. The goals of this evolution are objectivity and efficiency. Hence, the analysis of changes in style, presentation and argument of scientific articles allow to describe broader changes in the context of science itself.

1.2.1. The scientific article in the 17th century

Compared to those of 20th and 21st centuries, early scientific articles seek to establish credibility by providing reliable testimony rather than technical details, qualitative experience rather than quantitative experiments and observations in support of a theory (Gross, Harmon, Reidy, 2002). The following example is taken from the article "An Account of the Nature and Differences of the Juices, more Particularly, of our English Vegetables", written in 1665 by the Oxford-and Cambridge educated physician Martin Lister (1639 – 1712) and published in *Philosophical Transactions* in 1697:

> *The 21st of April, 1665. About eight in the Morning, I bored a hole in the body of a fair and large Bitch, and put in a Cork with a Quill in the middle; after a Moment or two it began to drop, but very softly: Some three Hours after I returned, and it*

had filled a Pint Glass, and then it dropped exceeding fast, viz. Every Pulse a Drop: This Liquor is not unpleasant to the Taste, and not thick or troubled: yet it looks as though some few drops of Milk were split in a Bason of Fountain Water (Lister, 1697).

In Lister's prose style, based on a personal narrative of discovery, facts occupy the center of the scene. The focus is on Lister himself as well as things he does or observes in nature. This is also testified by grammatical subjects and verbs used: the prose is largely constructed by simple noun phrases where the subject position is often occupied by the pronouns "I" and "It". In the text, there are a lot of impressionistic passages, based on qualitative evaluations ("a fair and large Bitch", "very softly", "not unpleasant to the Taste"). What is evident is that Lister's prose lacks the power of a technical vocabulary: he is forced to describe the natural objects he scrutinizes using metaphors and similes. As pointed out by Gross and colleagues: "His [Lister's] descriptions evoke nature at the price of systematic understanding; indeed, they evoke precisely because systematic understanding is lacking. This understanding is the gift of the theoretical and phenomenological vocabulary of the mature sciences" (Gross, Harmon, Reidy, 2002, p. 19).

Regarding presentation, since the amount of scientific literature in the 17th century was manageably small and many articles were short and meant to be read aloud in front of a learned audience sharing a curiosity about nature and technology, finding subsystems are relatively undeveloped. Headings are often not parallel in meaning and not particularly prominent (set in a type size smaller than that of the text): the approach toward systematization is casual rather than systematic. Similarly, due to the small dimensions of the audience, citations are often mere reminders of mutually possessed books and articles; they are few in numbers, and few articles have them. In Lister's article, for example, when presents, "citation are so general as to appear to be virtually unusable as a guide to actually finding the cited texts" (Gross, Harmon, Reidy, 2002; p. 19).

In general, style and presentation features of early scientific articles reflect the Baconian working philosophy that characterized science, and particularly English science, in 17th century. In a letter to the English botanist John Ray, Lister wrote: "For my part, I think it absolutely necessary that the exact and minute distinction of things precede our learning by particular experiments, what different parts each body or thing may consist of" and "Nature will be its own Interpreter in this, as well as in all other matters of natural philosophy" (quoted in Gross, Harmon, Reidy, 2002; p. 19). Given the faith that the facts will speak for themselves, explanatory talk is rare in 17th articles and connections with broader theories lack. In general, as previously said, authors seek to establish their credibility by means of reliable testimony and qualitative experience.

The great dream of English science - the Bacon's dream of a museum containing a specimen of every scientific fact - was pursued indifferently by amateurs and scientists, as no clear cut-demarcation existed between these categories: they all considered themselves to be the members of the "Republic of science" (Bensaude-Vincet, 2001). Slightly different was the situation in France, where the early professionalization of science through the Académie Royale des Sciences led to a bigger emphasis on "quantification, mathematical and mechanical explanations for acquired facts, and use of observations and experimental results as stepping stones to theory" (Gross, Harmon, Reidy, 2002; pp. 229).

1.2.2. The scientific article in the 18th century

Though 17th-century modes of communication persisted, the 18th century was also an age of transition. Moreover, it was also the golden age of the scientific societies, whose proliferation produced an increased number of sponsored scientific journals, along with privately published ones (McClellan, 1985). During this century, scientific articles were still characterized by narrative and epistolary conventions, explicitly personal and social judgments, and tolerance for emotional expression. At the same time, though, the social and the personal often fade into the background of the explanation of the natural world through measurement, calculation, and empirical observation (Gross, Harmon, Reidy, 2002; p. 69). Several examples are reported by Gross and colleagues. The following, on the transit of Venus and the eclipse of the sun, is taken from an English scientific article published in 1769 and clearly reveals the persistence of a narrative approach:

> *The weather, on the morning of the 3rd of June, was very unfavourable, both at the observatory of the Earl of Macclesfield and also here at Oxford, that there was very little reason to expect that we should be able to make any observation. But here, a few minutes before noon, the clouds began to break, and I was enabled to observe the transit of the Sun's consequent limb over the meridian. At one o'clock in the afternoon, the sky was again overcast, and it rained for some time; but towards three o'clock, the cloud were dispersed, the Sun shone out clearly, and at five o'clock there was hardly a cloud to be seen. The proceeding evening was also so very favourable, that the several persons who proposed to make observations of the transit, had an opportunity of adjusting their instruments.*

On the contrary, the following example, taken from a scientific article published in 1797 in a French journal, show changes in the direction of modern science norms:

> *The beginning of the central occultation is at 11:49 P.M. under 250° in longitude and 39° north latitude with the rising of the moon during the day, at the western coast of California. The mean [is] at 1:11 A.M. at night under 350° longitude and 54 ½° n[orth] latitude in the Atlantic ocean n[orthwards] over the Azores. The end of the central occultation [is] at 2:34 at the nocturnal setting of the moon under 58° longitude and 22° north latitude at Mecca in Arabia. This occultation [is] visible primarily and for the most part in the evening in North America, over the Atlantic ocean, Great Britain, France, Germany Poland, Italy, Anatolia, Arabia, and Egypt.*

In general, some trends in 18^{th}-century prose style will persist throughout the next two centuries: a shift from the scientist to his science and from subjective to objective prose; a shift towards more nuanced assertions; a shift from the individual scientist to the research network, supported by an increase in citations; a shift from the reporting of observed particulars to measurements and calculations, supported by the rise in quantitative expressions; a shift to the complex noun phrase as the grammatical unit for the conceptual content of science; a shift in the direction of syntactic simplicity, as measured by decreasing sentence length and clausal density (Gross, Harmon, Reidy, 2002).

Another important characteristic which differentiates 18^{th}-century and 17^{th}-century scientific articles is the more frequent exploitation of presentational features. As the century progresses, an increased number of articles report headings and comprehensive introductions and conclusions. Titles are usually thematic, fairly specific, free from technical terminology, and followed by authors designations to which credentials are often appended (e.g. professional credential, institutional affiliation). Citations become fairly common, generally incorporated in the text or placed at the bottom of the page. 18th-century scientific articles, unlike those of the previous century, often have an introductive part whose functions are similar of those of modern scientific articles: define an intellectual territory, establish a niche, occupy that niche (Swales, 1990). Similarly, conclusions closely approximate 20^{th}-century norms. The final paragraph usually deliberately links to a theory, tries to address the future of the field, and gives a clear indication of a research program.

No dramatic changes occurred between the 17th and the 18th century regarding argumentation: "Observational articles, with and without a theoretical component, dominate the pages of journals. Experimental, theoretical, methodological, and mathematical types all lag considerably behind" (Gross, Harmon, Reidy, 2002, p. 93). However, some changes occurred. Differences observed in the 17th century between English and French scientific articles vanish in the 18th century: both reflect a heightened interest in experimental and methodological aspects, both place equal emphasis on quantification. Although many scientists continue to only observe and experiment, the simple acquisition of facts become, especially in the last quarter century, no longer sufficient: a rise can be noted regarding the presence of explanations. Gross and colleagues explain this phenomenon through the words of Comte de Buffon, one of the greatest French scientists and prose stylists of the 18th century: "It is necessary to try to rise to something that is greater and more worthy of our time; it is necessary to combine observations, generalize the facts, link them through the power of analogies, and try to arrive at that high degree of knowledge where we can compare Nature with herself in her great operations, and where we can finally find ways to perfect the different parts of Physics" (quoted in Gross, Harmon, Reidy, 2002, p. 94). Causal-mechanical explanations begin to crop up regularly, explanations of temperature variations in terms of wind directions, cardiac function in terms of the structure of the heart, earthquakes in terms of subterranean water pressure (Gross, Harmon, Reidy, 2002). However, during the 18th century, and particularly in its first part, cause is still thought to operate by means of immediate physical contact. Thus, explanations don't aspire to universality: they concerns that specific physical event, not all events of a kind.

1.2.3. The scientific article in the 19th century

At the foundation of the British Association for the Advancement of Science in 1831 William Whewell, English scientist, philosopher, theologian, and historian of science, suggested that membership should be restricted to those "who have published written papers in the memoirs of any learned society" (quoted in Stimson, 1968, p. 215). For the first time, a clear cut-demarcation between professional scientists and amateurs was outlined. According to Gross and colleagues, "this linking of journal publication with the scientific profession led to an influx of individual articles primarily aimed at subject-matter experts" (Gross, Harmon, Reidy, 2002, p. 117). It also led to the emergence of the first specialty journals in natural history and physical science, such as the *Archiv für Mikroskopische Anatomie* (Archive of Microscopic Anatomy), the *Journal de Pharmacie* *et de Chimie* (Journal of Pharmacy and Chemistry), and the *Transactions of the Entomological Society of London*. In addition, the number of scientific journals rose very steeply: they were 100 in the 18th century and became 10,000 in the 19th century (de Solla Price, 1986).

The professionalization of science also created new identities for scientists and excluded from the readership of scientific journals the self-instructed enthusiasts. Edward Schunck, a student of the great German chemist Justus von Liebig, wrote in 1889: “The marvelously rapid progress of chemistry during the last twenty years has made it difficult for the most industrious cultivator of the science to keep abreast of the knowledge of the day, and for a *dilettante* like myself one may say it is next to impossible. I confess myself painfully conscious of my defects in this respect” (quoted in Kargon, 1977, p. 147). Thus, science became a matter of institutionally trained individuals which lived by means of science alone. However, whereas in the 20th century the scientists’ audience is a well-defined system of specialists, generally considered the only possible audience of their communication, during the 19th-century specialists are not the only audience addressed in scientific journals. “Readers of the same journal can be addressed as scientists per se or, more generally, as professionals who happen to be scientists; as those interested more in pure science or more in its applications; as professionals within a specific discipline, or anyone with a general interest in science” (Gross, Harmon, Reidy, 2002, p. 119). This explains why, despite the growing separation between amateur and professional, many articles reflect avoidance of the highly technical and, in the same journals, original research reports, addressed to scientists as scientists, appeared next to scientific “news” and other contents which addressed scientists as professionals.

Regarding style, during the 19th century, a progressive shift from the person toward science can be noted. It is hence useful to analyze the differences between two scientific articles, reported by Gross and colleagues, published at the beginning and at the end of the century. The first one came from a French article of 1801:

> *The whole, uncovered in a earthenware receptacle, immediately fermented; four days sufficed to develop the aroma of true oriental opium.*
> *I kept back a part for future use, and thickened the other by heating it to no more than 40 degrees. This extract retained a very faint odor of laudanum; it was a mixture nearly equivalent to that of commercial opium, minus the odor and gas driven off by the heat.*

The first passage reports a mix of specific actions side by side with more abstract verbs. On the contrary, the second one, which came from an English article of 1897, shows a definite shift toward abstract verbs and noun phrases:

> *It is in regard to the relation between this massive variety, which corresponds most closely to the type described by Zirkel, and the porous form, that my field observations are unfortunately so imperfect. But little of the massive rock was seen and then nothing was observed to indicate that the two types belonged to different flows. On this account, and from the chemical identity of the two rocks, I am at present inclined to regard the leucite of Zirkel's report as a part of the same flow that is predominantly a more or less vesicular sanidine-leucite rock, described in succeeding pages as orendite.*

Gross and colleagues also argue that, during the 19th century, differences among languages (English, French, German) are relatively small. In their perspective, this is particularly interesting given the considerable syntactic differences between the three languages. Hence, this uniformity "suggests that an international style of science may in some respects have preceded the internationalization of the late 20th century" (Gross, Harmon, Reidy, 2002, p. 124).

Regarding presentation, 18th-century articles show a movement toward 20th-century norms of scientific communication. Titles are still thematic and specific but, unlike those of the preceding century, they are very likely to contain technical terminology. Moreover, titles start to have a typical syntactic structure, often containing a word meaning "concerning", such as "on" (e.g., "On the specific gravity of sea waters..."), which represents a social signaling that marks the entrance into the domain of science. Professional credentials, such as membership in a scientific society, a medical degree, a university title, are increasingly reported. According to Gross and colleagues, this general increase could be a consequence of the spreading of science from capital cities to periphery: "Scientists no longer know one another personally" (Gross, Harmon, Reidy, 2002, p. 129). The use of headings and citations also increases, anticipating the master finding system of late 20th century articles. Citations are still incorporated in the text, but with they are more often placed at the bottom of the page. Moreover, two practices started to diffuse: the abbreviation of words like "page" and "volume" and the abbreviation of the titles of periodicals. Complete introductions (territory defined, niche established and occupied) are present in most of 19th-century articles, whereas scenic introductions reporting weather conditions definitively vanish from the pages of scientific literature.

Similarly, conclusions are present in the most of scientific articles of the time, often respecting current norms: adding insights, suggesting wider significance, making recommendations for future research. Finally, visual start to become very frequent: tables and figures are integrated into the text, with an increased use of numbered figures and legends. In general, evidence shows a master presentational system approaching maturity; formal elements are meaningfully separated and coordinate the communication units: title and author credits, headings, equations segregated from the text, visual provided with legends, and citations standardized as to format and position. Finally, introductions and conclusions prepared readers for the content of the article, summarized it and propose what is going to be next.

Just as in preceding centuries, in the 19th century, scientists still argue for facts: qualitative description is the base for factual reliability. However, there is no reliance upon witnessing, neither concerning regarding the accuracy of instruments or the purity of reagents. According to Gross and colleagues, by then these aspects are probably already accepted and no longer the subject of the scientific discourse: "Nineteen-century science is increasingly dominated by a passion for factual precision, coupled with systematization, and leading more and more to carefully articulated theorizing" (Gross, Harmon, Reidy, 2002, pp. 158-159). For example taxonomy, through the use of Linnean binomial, becomes the science of the classification of living matter. On the contrary, other disciplines, such as historical science and geology, undergo a sensible shift from description to theory, "from a science of facts to a science of causes", whereas others, as in the case of physics and chemistry, move steadily in the direction of turning qualitative into quantitative facts. Each science starts to develop its own explanatory structure, by carefully articulated theorizing through argument. As reported by Gross and colleagues: "This task is routinely accomplished in a special register of ordinary language distinguished not only by its technical terminology but also by its inferential explicitness, an explicitness that often requires not only verbal but also visual language. At times the overriding need for explicitness also requires the use of an artificial language: mathematics" (Gross, Harmon, Reidy, 2002, p. 160).

1.2.4. The scientific article in the 20th century

According to Menard, science in the 20th century is mainly characterized by two tendencies: hyperspecialization and global professionalization (Menard, 1971). These trends have led to the emerging of an international network of authors, readers, publishers, and editors that support annual production of "hundreds of thousands of articles in thousands of journals" (Gross, Harmon, Reidy, 2002, p. 161). During the century this rampant specialization and mass production goes side by side with progressive standardization, as reflected in the proliferation of style sheets and manuals seeking to promote specific communicative norms.

In the 20th century, the modern scientific style completes its maturing process, adapting from a natural language where people are the central characters to a specialized talk where the focus of attention is on things and explanations. As a result of this evolution, scientific prose become dominated by the passive voice and a neutered style; this can be seen in the following passage from an English article of 1990:

> *This finding contradicts the conclusion of Klein et al. [1987] based on Voyager observations. How can this discrepancy be explained? Is it caused by differences in the measurements, one set of measurements presumably being in error? The question is not easily answered because of the different ways in which the data are analyzed by the Pioneer and Voyager investigators. Thus it is not possible to compare figure 5 with the corresponding Voyager measurements.*

As reported by Gross and colleagues: "This neutered style leaves the impression that the authors wish only objectively to evaluate and explain the available facts, not participate in an intellectual donnybrook" (Gross, Harmon, Reidy, 2002, p. 164). Or, as Bazerman puts it: "While science-in-the-making is deeply contentious, science-once-made appears co-operative and harmonious, as traces of division re excised within a narrative of progress towards current belief, taken as true" (Bazerman in Martin & Veel, 1998, pp. 16). This is also demonstrated by an increased use of hedging, as "This is probably so" or "They might be wrong". Such hedging fills both stylistic and argumentative functions. It communicates doubt where the absence of the personal voice automatically gives the impression of authority and assurance while avoiding the charge of overclaiming. The "personal" voice is indeed completely absent in the modern scientific literature. Gross argues that: "Scientific prose [...] generally excludes any device that shifts the reader's attention from the world that language creates to language itself as a resource for creating worlds" (Gross, 1990, pp. 150). Hence, the author's voice remains subservient to the presentation of knowledge claims and accompanying evidence. Other changes can be noted in the attempt to manage the increasing cognitive complexity. Gross and colleagues stated that "as science has grown more theoretically and methodologically complex, its grammar has adapted by adding substantially to the complexity in its noun phrases and by deployment of specialized literary devices (such as fused noun-strings and abbreviations) aimed at compactly conveying technical messages to small groups of highly trained readers in a specialized research field" (Gross, Harmon, Reidy, 2002, p. 167). Behind the use of noun phrases, there is, according to Perelman and Olbrechts-Tyteca, the search of a rhetorical effect that makes "a statement timeless and, in consequence, beyond the limits of subjectivity and bias" (Perelman & Olbrechts-Tyteca, 1969). A further level of abstraction is then added by the increased use of noun strings (e.g. "15-day-old mouse embryo dorsal root ganglia"), quantitative expressions, and abbreviations.

Also the number of citations increases during the 20th century. According to Gross and colleagues, this sudden jump in citational density reflects an important social change: "By means of diligent citation practices, the various scientific communities reward their members for having made their research public" (Gross, Harmon, Reidy, 2002, p. 170). Citations become then an intellectual payment for having provided information. The citational attention also become a measure of a scientist competence: the more cited his or her work, the more likely he or she will receive a promotion, additional research funding, or publication in elite journals. A system of rewarding attention that, according to Gross and colleagues, ensures the efficiency and productivity of the overall knowledge-manufacturing machine.

During the 20th century, the scientific article has grown specific and stable parts: title and byline, abstract, introduction, list of citations and acknowledgments, a finding system, graphics legends and numbers, numbered equations and references, and others. Overall, "these measures have helped improve communicative efficiency, in partial compensation of the growing conceptual and semantic complexities of the subject matter and the purposeful narrowing of the intended audience" (Gross, Harmon, Reidy, 2002, p. 172). Of enormous importance is the increased relevance of the three-parts front matter: title, which announces the article's main theme or the central claim; byline, which establishes authors' professional standing within the scientific community; the abstract, which concisely states the article's key points. These three element act as a screening device, "enticing some readers to want to read more, signaling to others they might want to direct their attention elsewhere" (Gross, Harmon, Reidy, 2002, p. 174). The abstract in particular, diffused mainly in the second half of the century, allows to rapidly feature the essence of the article, as it usually reports, in a few lines, a brief introduction, methods, the authors' major claims, and conclusions. Also significant is the growing relevance of the introduction of the scientific article, which now stably defines a research territory, establishes a limited research problem within that territory and provide solutions to that problem (Swales, 1990), and of the conclusive part. The last has evolved as having three stable components: original claims derived from having solved the problem defined in the introduction, wider significance of those claims, and suggestions on future work to validate and extend the initial claims. Those parts are particularly relevant as they place findings in the context of current disciplinary debates and make a case for the continuing value of the authors' research program. Finally, as previously said, one of the most important change that reveals the attempt to manage the increasing complexity of science concern the development of a complete finding system, composed by headings and subheadings, numbered equations, numbered figures and tables, and citations tagged within the text (by means of number or author and date).

As previously reported, during the 20th century is no longer sufficient, for a scientist, to put together an array of facts describing what he or she observed. On the contrary, facts must be argued through a multimedia collage of words and pictures exhibiting methods, new knowledge claims, theoretical explanations, visual evidence in support of the facts. Unlike preceding centuries, an article always include some engagement with theory. Facts in the form of quantitative representations are always preferred to qualitative evaluations, and authors offer some mechanistic or mathematical (or appropriate to their discipline orientation) explanation for them. In line with this, experiments are generally preferred to observations and are more often performed in an artificial setting such as research laboratories. Accordingly, increased attention is devoted to methods: the amount of research equipment and techniques for querying nature. Modern scientists provide detailed descriptions of the methodology used to give weight to the quantitative results that are the products of the research: only if the reader judges the methodological details as a plausible strategy for solving the problem the article will be likely viewed as authentic science. As stated by Perelman and Olbrechts-Tyteca: "In contemporary natural [and physical] sciences, facts are increasingly subordinated to the possibility of measurement, in the broad sense of that term. The natural [and physical] sciences display resistance to any observation which cannot be fitted into a system of measurement" (Perelman & Olbrechts-Tyteca, 1969). Finally, it has to be noted that in the 20th century the modern scientific argument has two well-defined strata: verbal and visual. According to Gross and colleagues: "The verbal stratum typically consists of a problem setting introduction, detailed information on research equipment and procedures for solving the problem, quantitatively based facts deduced from the applied equipment and procedures, theoretical explanations of the facts, and summaries of the new knowledge claims generated by the procedures" whereas "the visual text establishes facts and explanations by means of data arranged in columns and rows and graphs depicting data trends and mechanisms, as well as schematics and photographs" (Gross, Harmon, Reidy, 2002, pp. 212-213). Of course, this interaction between verbal and visual components will come to its major expression thanks to the "computer revolution" and the emergence of electronic scientific journals, as it will be discussed in the following paragraphs.

1.2.5. The medialization of science

Science in 20th century is not only characterized by hyperspecialization and global professionalization. The emergence of a mass society caused the legitimacy of political organizations, individual politicians, and governments, but also of societal institutions like science to be largely determined by the role of media as they assume a central communicating function in mass democracies. Science, like politics, begins to adapt to the criteria of mass media communication as it starts to demand public legitimation. However, as argued by Peter Weingart, this opening of science to the public "seems to imply that the criteria of scientific knowledge generation are losing their orienting function" (Weingart, in Rödder et al., 2012). Thus, the thesis of "medialization of science" stipulates that during the second half of the 20th century the relationship between science and the media has changed substantially, due to growing dominance of the mass media in public communication, and that these changes have influenced the way knowledge is created and communicated.

Several studies have attempted to determine the effects of this orientation of science to the media (e.g., Peters in Cheng et al., 2008; Weingart, 1998;). According to Weingart, there is general agreement on three observations: "(1) The orientation of science to the mass media has grown more intense; (2) This may create tensions of different degrees of severity within science because the orientation to the media is in conflict with rules and values prevailing in science; (3) These tensions are expressed in the dilemma in which scientists find themselves because the demand to communicate with the public has become part of their legitimate exercises in the context of mass democracies whose publics and political leaderships no longer recognize and accept the professional elites' privilege of virtual unaccountability" (Weingart, in Rödder et al., 2012, p. 20). Weingart describes the thesis of 'medialization' of sciences through the conceptual framework of systems theory, "for the simple reason that it proceeds from the very fundamental distinction between science and the media as the result of the historical, functional differentiation of modern societies" (Weingart, in Rödder et al., 2012, p. 24). In this perspective, science and the media are two of a set of functional systems which constitutes modern societies (politics, economics, law, religion, science and the media), each defined by an operating code (e.g., *truth* for science, *power* for politics, *profit* for economics) (Luhmann, 1995). According to Luhmann, inter-systems relations can exist in the form of *coupling* or *resonance*.

In biology, *coupling* refers to the mutual dependencies between systems and their environments, whereas applied to social contexts it can be interpreted as the mutual dependency that exists in the form of expectations and services. In the case of coupling between science and the media, as reported by Weingart: “Science provides a steady stream of information to the media. Not all of it is interesting to them, but some is: the discovery of a star, the spread of a virus, the extinction of a particular species are all information communicated by science on which the media rely for their news reporting. The mass media, on the other hand, are coupled with science because science relies on the media’s focusing of public attention on important discoveries and, indirectly, demonstrating its utility and legitimating its costs” (Weingart, in Rödder et al., 2012, p. 25). *Resonance* between systems is instead a metaphor taken from physics, where it denotes the irritation or agitation of a system capable of oscillation. “The crucial variable is resonance frequency which means that oscillations caused by energy input from outside the system may cumulate and, in the extreme case, lead to catastrophic destruction” (Weingart, in Rödder et al., 2012, p. 26). Tension can exist when one of the two coupled systems, to respond to the requests of the environment, finally loses its function. The medialization thesis, however, focuses on the science side of resonance effects. Here an example. in 2015 the scientific journal *Science*, considered one of the most reliable in the world, published a paper titled *Cancer etiology. Variation in cancer risk among tissues can be explained by the number of stem cell division*- It was then followed by a second article in 2017, in which the same authors, Cristian Tomasetti and Bert Vogelstein, claimed that only a third of the variation in cancer risk among tissues would be attributable to environmental factors or inherited predispositions (Tomasetti & Vogelstein, 2015). The remaining two thirds, indeed, would be due to "bad luck": random mutations that arise during DNA replication in normal, non cancerous stem cells. Immediately, media from all over the world published breaking news reporting that the risk of developing cancer would be mainly due to bad luck and, consequently, not to environmental or lifestyle factors such as smoke, alcohol, solar radiations, and obesity (e.g., a CNN article titled *'Bad luck' mutations increase cancer risk more than behavior, study says*) (Scutti, 2017). At the same time, several scientists stated that the article by Tomasetti and Vogelstein was methodologically weak and that the two authors’ claims were unreliable (e.g. Rozhok et al., 2015; Weinberg & Zaykin, 2015). The Italian epidemiologist Paolo Vineis, for example, wrote in an article that there was “a profound misunderstanding in the calculations of Tomasetti and Vogelstein, who have obviously failed to get rid of the problem" and that their reasoning was "too simple to be true". So one can ask: why did an influential journal as Science publish an article like that? According to Vineis: "Motivation lies in the desire of scientific journals to draw the attention of the first pages of newspapers" (Vineis, 2017).

In conclusion, the thesis of 'medializaton' of science argues that the orientation of science to the media could lead to the displacement of epistemic criteria of novelty, relevance, and robustness by the media's criteria of news values. As the reference to the public, via the media, is perceived to be important for the legitimacy of research, it may have repercussions on the validity of theories and methods. Even top journals' orientation to the mass media seems to result in a selection of more spectacular or surprising research results, contributing to the creation of topical cycles which steer attention in the selection of research topics. As Weingart stated: "When become more important to publish an article containing 'sensational news' rather than to make sure that the news is 'true' and recognized as such by the scientific community, obviously the mass media's public is considered more important than the 'public' of peers [...]. Strictly speaking, orientation to the media has then replaced orientation to 'truth'" (Weingart, in Rödder et al., 2012, p. 30).

2. Web-based scholarly communication

As with any kind of communication, even scholarly has been revolutionized since the arrival of the Internet: the Web has indisputably changed the way researchers share information. Even if the peer-review article continues to play a crucial part in the certification, communication, and recording of scientific research, in the electronic environment it only represents a single point on a potential continuum of communication. As argued by Frankel and colleagues: "The electronic medium unquestionably creates added value in publication through the speed with which it can disseminate information, the size of the audience it can reach efficiently, its enhanced indexing and search capabilities, its hypertext linkages to a wide range of material, its ability to be updated and corrected as needed, its interactivity, which enables real-time exchanges between authors and readers, and its multimedia format, which can incorporate video and sound into text" (Frankel et al., 2000, p. 251). However, the enhanced possibilities of electronic publishing have also changed the norms and practices that traditionally established credibility to scientific articles appearing in peer-reviewed journals.

Scholarly communication has increasingly moved toward a new publishing model that emphasizes conference papers, preprint archives, and the online availability of scientific articles. Indeed, even if "much of this communication will eventually make its way into the traditional published literature as journal articles, the time required for publication and citation indexing may be too slow for the progress of research and development in the sciences" (Goodrum et al., 2001). For these reasons authors, institutions, and archives are more often making formal research publicly available on their websites in the form of PDF, Postscript, and other formats before it is published in journals and books. The once called "grey literature" (conference proceedings, preprints, theses, reports), made more accessible by the electronic environment, may more effectively fulfil some of the functions of a scholarly publication. For example, an electronic preprint archive is a more effective vehicle for timely communication and for establishing chronological priority than a scholarly journal (Halliday, 2001).

As previously said, certified scientific articles are critical in determining the trustworthiness of scientists and, importantly, they have a role in career advancement. Kling and McKim argue that scholarly publishing is "an activity engaged in by scholars who primarily want their reports to be widely read and credited by their target audience" (Kling & McKim, 1999, p. 893). Their focus is on the community, on scholarly communication as a social process rather than a production process. A publication can be defined as effective concerning three dimensions which serve both authors and readers: publicity, access, and trustworthiness.

Hence, the need to define what constitutes a formal scientific publication in the electronic environment is of considerable importance. In 2000, Frankel and colleagues proposed a list of characteristics that a document should have to be considered of value to the scientific community (Frankel et al., 2000):

- It must be durably recorded on some medium;
- It must have a persistent access mechanism so that it is reliably accessible and retrievable over time;
- It must be immutable (i.e. it should remain in the same form);
- It must be publicly available.

However, they argue that the following features are also required: authenticity must be guaranteed (i.e. versions should be certified as authentic and protected from change after publication); an identifier must identify the work unambiguously; a bibliographic record (metadata) must describe the work and its various versions, which must be public and freely accessible for any given address location; a commitment to continuing public access and retrievability must be guaranteed; availability of the document must be notified to the community; a commitment not to withdraw the document must be guaranteed; the version of the document which has been submitted for a process of certification should be identified as such in its bibliographic metadata.

The situation is even more complex in the Web 2.0, which will be considered in the following chapter. Web 2.0 can be defined as “a variety of different meanings that include an increased emphasis on user-generated content, data and content sharing and collaborative effort, together with the use of various kinds of social software, new ways of interacting with web-based applications, and the use of the Web as a platform for generating, re-purposing and consuming content” (Anderson, 2007). There exists a wide variety of Internet-based services used by researchers that could be termed Web 2.0, such as generic services arising from the effort of commercial providers, tools adapted for specific worksites or research communities, and services provided by publishers and libraries. Furthermore, as stated by Procter and colleagues, “in addition to the formal publication of articles, Web 2.0 is relevant to a large number of scholarly communication practices, ranging from promoting published papers to the sharing of digital research artifacts and the coordination of collaborative work” (Procton et al., 2010). Indeed, as it will be discussed in the next chapter, actually not only scientists use blogs and social networks to promote their research findings, but also scientific journals do the same.

CHAPTER 2

Scholarly communication on Twitter

1. Scholarly communication and research dissemination on social media

With the advent of Web 2.0, online services shifted from offering channels for networked communication to becoming interactive vehicles for networked sociality. Platforms like Myspace (2003), Facebook (2004), Flickr (2004), Youtube (2005), Twitter (2006) began to offer web tools that sparked new online communication strategies: e.g., microblogging, video sharing, chatting, and video conferencing (Van Dijck, 2013). As argued by Van Zyl, social media provide a great space for individual Internet users, not only for the basic data storage needs, but also for the users' psychological experience requirements, such as to "be found", "be authorized" and "be admired", expanding their opinions from an individual to a participatory perspective of information transmission (Van Zyl, 2009). Although the distribution of scientific information has retained part of its traditional structures, also scholarly communication and research dissemination have been substantially affected by these new ways of communication (Meadows, 2003). The social and interactive web brought additional challenges as well as possible advantages. For example, social media help to fulfill the demand for cheap, instant communication between researchers in a context of growing collaborative and interdisciplinary research (Nicholas & Rowlands, 2011) **(Fig. 1)**. With the establishment of this new kind of network society (Katz et al., 2001; Dahlgren, 2005), researchers met an evolution in scholarly communication, requiring more knowledge from all kinds of communication processes (Thorin, 2006).

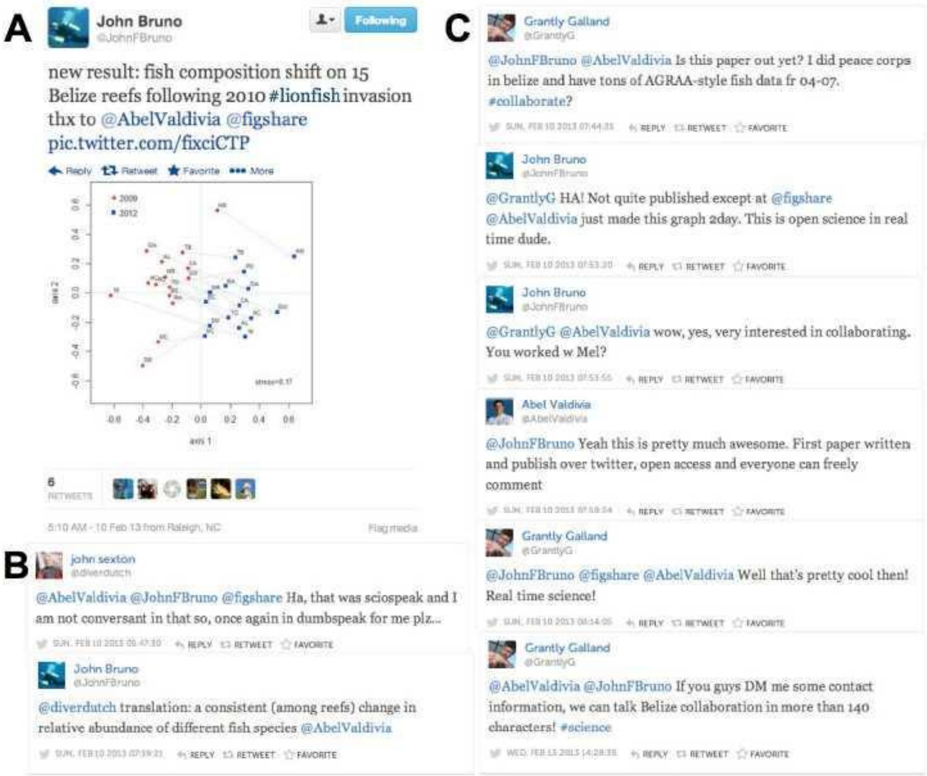


Fig. 1 An example of how tweeting can move ideas forward and contribute to scientific outputs (Darling et al., 2013).

Participation, however, is the main challenge in the context of Web 2.0 (Miller, 2005): individuals are not only capable of contributing to the new information, but also indirectly asked to do that. Under Web 2.0 circumstances, researchers could join all kinds of virtual scientific communities and publish their findings in blogs, wikis, social networks, etc. Moreover, some environments (e.g., Google Docs) are also suitable to cultivate the habit of online scholarly writing and collective writing, especially in the case of collaboration between different research fields. As a result, more online references and multimedia resources from social media are forcing the online scholarly information to be more reliable and accurate. In this sense, evidence shows that the rate of web-based quotations referenced in scientific articles has risen from 1.9% to 16% in ten years (Chen et al., 2009). Different forms of copyright now help academic writers to use and publish their findings and opinions on social media, making the scholarly outcome more reliable and hence attracting more researchers to write in such platforms (Wilson, 2008). Moreover, social media offer more routes to the researchers to express their ideas. They may present their opinions not only through written contents but also through multimedia, including audio, broadcast, video, photo and so on: social media make knowledge sharing, one of the motivations of scholarly communication, a multi-dimensional infrastructure. This multi-dimensional improvement of knowledge sharing satisfies the needs of researchers in their discussions and interactions with others on interdisciplinary subjects. Overall, Web 2.0 seems to have influences on information behavior, moving scholarly communication into the platform of social media (Voss and Procter, 2009).

Researchers are using these tools to support every phase of the research lifecycle: from identifying research opportunities to disseminating findings at the end. However, according to Nicholas and Rowlands, "the three most popular social media tools in a research setting are those for collaborative authoring, conferencing, and scheduling meetings" (Nicholas & Rowlands, 2011, p. 78) **(Fig.2)**. In these contexts, the most used tools tend to be mainstream anchor technologies or brands, like Skype, Google Docs, Twitter, and YouTube. Indeed, researchers seem to be largely appropriating generic tools rather than using specialist or custom-built solutions like Academia.edu and Mendeley (Nicholas & Rowlands, 2011, p. 80).

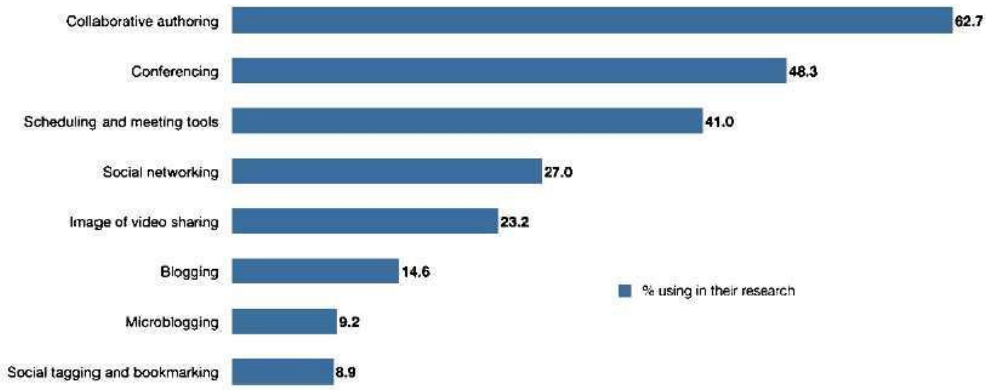


Fig. 2 Popularity of various types of social media in research. Active social media users: percentages using each category of tool (Nicholas & Rowlands, 2011)

Highly inclusive surveys also considered operationalizing social media and networking tools such as Skype and Wikipedia. These studies show high degrees of use at the individual level, with percentages as high as 75% (Tenopir et al., 2013) and 80 percent (Procter et al., 2010), although results vary among fields and by demographic characteristics (e.g., gender, age).

However, looking more closely at particular social media platforms a substantial variation appears, with collaborative authoring tools (Rowlands et al., 2011) and LinkedIn (Haustein et al., 2014; Mas-Bleda et al., 2014) among the most popular. Lower rates have been found for other social media sites: rates of Twitter use for academics is around 10% (Grande et al., 2014; Procter et al., 2010; Pscheida et al., 2013; Rowlands et al., 2011), trailed by Mendeley (6%), Slideshare (4%), and Academia.edu (2 percent) (Mas-Bleda et al., 2014). Also in the study by Rowlands and colleagues, it emerged that microblogging had not yet gained significant popularity among scholars, as only 9.2% stated that they used Twitter or similar platforms in their research. However, they found some disciplinary differences in how researchers are using social media in general, as natural scientists in their study were the most prominent users. The authors suggest that it may not take long before social scientists and humanities researchers catch up: while there were some differences between disciplines, no differences between how different age groups use social media were discovered (Rowlands et al., 2011).

Individual motivations to use social media for scholarly communication vary significantly by age (Nicholas et al., 2014), country (Mou, 2014; Nicholas et al., 2014), and platforms (Mohammadi et al., 2015). The same can be said for academic institutions, which have implemented social media tools to varying degrees. As reported by Hausten and colleagues, motivations for institutional use of social media range from faculty development (Cahn et al., 2013) to pedagogy (Kalashyan et al., 2013; Hausten et al., 2015). Similarly, academic libraries have been early adopters of social media tools, with nearly all libraries maintaining an institutional Twitter and Facebook account, and often hosting a blog (Boateng & Quan Liu, 2014). Finally, as it will be discussed in the next paragraphs, also scientific journals have increasingly adopted social media tools, using commenting, blogging and social networking (Kortelainen & Katvala, 2012; Stewart et al., 2013).

2. Scholarly communication and research dissemination on Twitter

One of the social media services that researchers use in scholarly communication is Twitter, a microblogging and social media platform that allows users to post/publish short messages of up to 140 characters including spaces (recently, the limit has been elevated to 280 characters). A user can follow any other user, and the user being followed doesn't need to follow back. Being a follower on Twitter means that the users view on their feed all the messages (called tweets) from those they follow. The common practice of responding to a tweet has evolved into well-defined markup culture: RT stands for retweet, '@' followed by a user identifier addresses the user, and '#' followed by a word represents a hashtag. The use of hashtags allows the user to group tweets about the same topic. For example, hashtags are frequently used at scientific conferences as a convenient way to collect all tweets about the conference and to ensure that participants can quickly access relevant tweets. Because of the unique features of these types of tweets (RT, @username, #hashtag) they can be extracted automatically from a corpus of tweets and used to focus on certain type of use of Twitter.

Twitter has 330 million monthly active users worldwide (up to January 1st, 2018), making it the ninth largest social network in the world (Statista, 2017). In the past years, it has gained a lot of media coverage, for instance as an efficient and rapid tool for sharing emergency information (Ash, 2011). The service has also been studied for a wide range of research goals from political elections (Hong & Nadler, 2012), governmental contexts (Golbeck et al., 2010), spreading of misinformation (Zollo et al., 2015), natural disasters (Earle et al., 2011), protest movements (Harlow & Johnson, 2011), and health information sharing (Scanfeld et al., 2010).

Disciplinary differences in Twitter use have been reported by Holmberg and Thelwall. The two researchers found that "digital humanities and cognitive science researchers use Twitter more for conversations than do the other disciplines, and substantially more than do the researchers in biochemistry and economics; in economics, Twitter is mostly used to share links, while this possibility does not seem to be frequently used in digital humanities". They also reported that "Twitter is used by experienced researchers more for scholarly communication in biochemistry, cheminformatics, astrophysics, and digital humanities, than in sociology, economics, history of science and social network analysis" (Holmberg & Thelwall, 2014, pp. 1038 – 1039). Findings from Holmberg and Thelwall (2014) also showed that researchers shared more links than the average Twitter users and that they tweeted contents that were usually more informative. That difference was particularly clear in their analysis of retweets, where between 62% and 75% of the tweets forwarded by the researchers included links to some information resources (Holmberg & Thelwall, 2014).

2.1. Twitter in the cycle of scientific publication

Twitter can influence the whole life cycle of a scientific publication, from ideation and collaboration on a spark of an idea to the communication of the finished product. In 2013 Darling and colleagues listed and discussed the benefits of Twitter for academics and scientific institutions (Darling et al., 2013):

- **Making connections:** the most obvious and relevant contribution of social media to scientific output is speeding up connections between scientists. Informal scholarly conversations are moving out of the ‘faculty lounge’ to online social media platforms, such as Twitter (Priem, 2013). Indeed, social media can provide scientists with a much larger virtual environment of professional connections beyond their institutions, as well as access to researchers outside of their discipline to accelerate interdisciplinary research.

- **Moving ideas forward:** Twitter can rapidly increase connections to like-minded researchers, both within one’s research field and outside it. Rapid communications through social media provide novel tools to quickly develop pre-review scientific ideas before submitting the final product to a peer-reviewed journal.
- **Communicating and discussing published ideas:** the final step in the scientific life cycle is communicating the findings of your scientific publication to the interested scientific community. Twitter can have a role in this, as it will be described in the following paragraphs.
- **Increasing reach:** Twitter also provides a wide virtual audience for the development of ideas and an echo chamber for the dissemination of published papers. Active research dissemination requires more time, effort and connections, but Twitter can facilitate this task. “The two main advantages of tweeting in terms of dissemination are that tweets allow you to convey the most interesting discoveries or conclusions of a new paper both more informally and more informatively than a paper’s title can” (Darling et al., 2013, p. 16). These advantages are even being taken into consideration by some journals (e.g., Methods in Ecology and Evolution, Journal of Ecology) and conferences (the 2013 International Congress for Conservation Biology), which require each submission to be accompanied by a tweetable abstract. Sharing published work can also restart the scientific life cycle if another researcher follows up on an idea or forms a new collaboration based on a citation tweet. Because the followers of scientists comprise not just academics, their tweets (and retweets) often reach also nongovernmental organizations, private industry, government agencies and non scientists. This means that science with applied or policy implications can reach people in decision-making positions. Indeed, tweeting directly to decision makers also makes it possible to reach such people, even if they are not your followers.
- **Increasing impact:** Tweeting can influence the numbers of citations. For example, articles published in the Journal of Medical Internet Research that were tweeted about frequently in the first three days following publication were 11 times more likely to be highly cited 17 to 29 months later than less-tweeted articles. Moreover, top-cited articles could be predicted quite accurately from their early tweeting frequency (Eysenbach, 2011). Similarly, Shuai and colleagues found that papers with more mentions on Twitter were associated with more downloads and early citations of papers (Shuai et al. 2012).

- **Providing post-publication critiques:** many scientific journals, particularly open-access ones, have tried to promote online discussion of published results (Neylon & Wu, 2009), but scientists have largely failed to engage in this type of post-publication critique. For example, as shown by Schriger and colleagues, less than 20% of articles in high-impact medical print journals that offered online commenting facilities received comments, and from 2005 to 2009, the proportion of journals offering this service declined (Schriger et al. 2011). Indeed, Twitter allows rapid, low-effort, and pointed comments that focus on the most serious problems with a published paper.

2.2. Tweeting links to academic articles

Providing links to outside content is a central convention developed by users of the 280-character social network. Posting links enables the user to point others to extended information on any given topic. As previously said, links to scientific articles are now frequently tweeted as well. Thelwall and colleagues argued that "from the perspective of the tweeter, the rewards for tweeting relevant research might include the social capital that accrues from performing a useful service, a reputation for identifying important new research, the attendant publicity for any personal articles tweeted, or even the altruistic pleasure that comes from helping others locate germane information" (Thelwall et al., 2013, p. 1). Priem and Costello defined the concept of *citation tweet*: "Direct or indirect links from a tweet to a peer-reviewed scholarly article online" (Priem & Costello, 2010, p. 2) (Fig. 3). In their study of 2013, Thelwall and colleagues analyzed a sample of 270 of randomly selected tweets produced by the Twitter accounts of 4 digital libraries (Wiley, ScienceDirect, Springer and JSTOR) and four large general journals (PLoS ONE, PNAS, Science, and Nature) to investigate how academic articles are tweeted. Results showed that, differently to other types of tweets (e.g., those mentioning commercial brands) (Jansen et al., 2009) those linking to scientific articles are typically objective, either including an article title or tweeting a brief summary of its key points. It seems that academic tweets usually don't give insights into the reception of articles by readers, except perhaps in unusual circumstances such as for controversial of ground-breaking research. The authors hence concluded that "tweet counts may still be a reasonable indicator of the notice that academics have taken of online articles" and that "the association between tweets and future citations seems reasonable and may well be true across different academic disciplines" (Thelwall et al., 2013, p. 6).

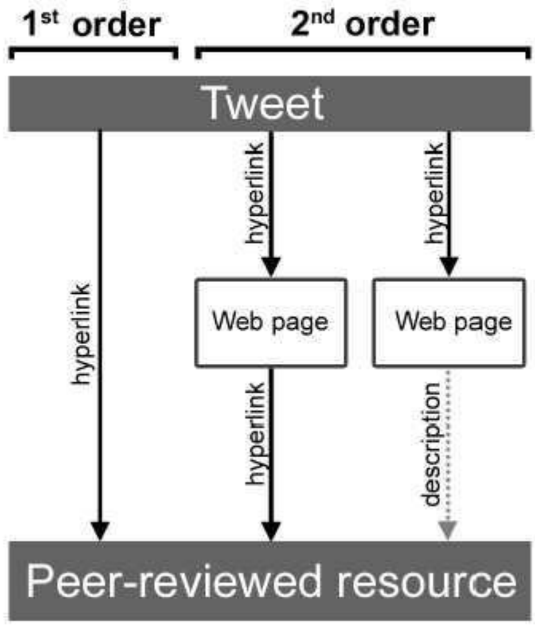


Fig. 3 Types of Twitter citations (Priem & Costello, 2010).

Priem and Costello (2010) demonstrated that citation tweets might be short-lived and reach only the user's followers, but the size of their audience may increase exponentially if they are retweeted. The authors found that 19% of links to peer-reviewed articles sent by a small sample of academics were retweets. In contrast, for example, nearly half (47%) of tweets sent by Nature Chemistry (2013) were retweeted, on average four times each. Admittedly, not all of Nature Chemistry's tweets had links (to papers, but also to blogs and other chemistry-related sites), and it is not clear whether tweets with links are more or less likely to be retweeted than those without. Nevertheless, Priem and Costello concluded that "a citation tweet that is subsequently retweeted can reach an immensely wide audience, with relatively little effort on the part of the initial author".

Hence, it is becoming increasingly clear that the simple number of citations in academic journals is a reductive way to measure the scientific impact of an article (Neylon and Wu 2009, Priem 2013). Eysenbach (2011) examined citation tweets, trying to determine whether they predict traditional citations, coining the term *tweetation*, which refers to a tweet containing a journal article link. He found a correlation, but cautioned against using Twitter-based metrics to replace traditional bibliometric measures: "Tweetations should be primarily seen as a metric for social impact and knowledge translation (how quickly new knowledge is taken up by the public) as well as a metric to measure public interest in a specific topic (what the public is paying attention to), while citations are primarily a metric for scholarly impact" (Eysenbach 2011, p. e123). Similarly, Thelwall and colleagues investigated Twitter and ten other social web services as potential citation tools. Their results provided strong evidence that six of the eleven metrics considered (tweets, Facebook wall posts, research highlights, blog, mentions, mainstream media mentions and forum posts) associate with citation counts (Thelwall et al., 2013). However, they also argued that the coverage of all such metrics is generally low and so they may only be useful to identify the occasional exceptional or above average article rather than as universal sources of evidence. Still, they concluded that their "results suggest that alternative metrics are related to citation counts, they might be able to capture the influence of scholarly publications on a wider and different section of their readership than citation counts, which reflect only the behaviour of publishing authors" (Thelwall et al., 2013, p. 6). The same opinion is expressed by Liu and colleagues: "Authors should pay more attention to the scholarly social impact that originates from active altmetrics and then participate more in related activities such as rating websites, noting, and commenting on articles. The publishers should attempt to launch an open peer review and consider scientific citizens' perspectives before deciding whether to publish. They should also explore the value and the applications of post-publication interactivity in terms of ratings, notes, or comments. Academic administrations should track the dissemination of published articles (in terms of multiple types of citation, ratings, comments, and notes) and access up-to-date altmetrics data to determine article quality or the impact context for tenure and promotion decisions" (Liu et al., 2013).

2.3. Tweeting from academic conferences

Formal conference presentations and congresses still play a relevant role in scholarly communication. However, a divided space with a front area for the speaker and a wider back area for the audience provides a physical platform for didactic transmission with limited interaction possibilities. Several research groups showed the existence of problems such as the lack of feedback, the nervousness about asking questions, the issues raised by the single speaker paradigm - where the focus on only one speaker can lead to a decrease in participation by others -, the reduction in collaboration and interaction due to the limiting factors of the setting (Anderson et al., 2003, Reinhardt et al., 2009). According to Ross and colleagues, the use of a digital backchannel such as Twitter represents a solution to such problems, providing "an irregular or unofficial means of communication which can extend beyond the lecture room to engage with scholars across the community" (Ross et al., 2011, p. 217). The term backchannel means that there are two channels of interaction operating simultaneously, one formal and one informal. Backchannel communication travels through informal channels as a secondary route of communication. Twitter use during conferences is associated with several benefits: being able to ask questions, or provide resources and references, changing the dynamics of the lecture room from a one-to-many transmission to a many-to-many interaction, without disrupting the main channel communication.

Ross and colleagues analyzed the use of Twitter as a backchannel for academic conferences, focusing on the Digital Humanities community in three different physical conferences in the academic field of digital humanities (Digital Humanities 2009, University of Maryland, 22-25th June 2009; That Camp 2009, George Mason University, 27-28th June 2009; and Digital Resources in the Arts and Humanities 2009, Queens University, Belfast, 7-9th September 2009). Unofficial Twitter backchannels were established using conference specific hashtags (#DH09, #THATCAMP and #DRHA09, #DRHA2009) to enable visible commentary and discussion. They found that conference hashtagged Twitter activity did not constitute a single distributed conversation but, rather "multiple monologues with a few intermittent, discontinuous, loosely joined dialogues between users". Moreover they noticed that "the real-time exchange and speed of review of shared ideas seems to create a context of users offering commentary and summaries and not spreading the ideas of others verbatim (Ross et al., 2011, p. 221).In their research, 66% (2054 Tweets) of the Tweets considered included direct references to other Twitter users, through the @ sign, as the source of a quote, object of a reply or debate. As argued by McNely, the use of mentions represents conversational and collaborative practice. By taking the appearance of the @ sign as an indicator for an act of conversation or attention-seeking behaviour, the use implies a form of collaborative writing activity, driving a conference community of practice who are involved in shared meaning-making and the co-construction of knowledge (McNely 2009). Interestingly, 10% of tweets were categorized as establishing an online presence within the Digital Humanities conference community. This does not suggest that users are self-indulgent, it does instead bring up that the users are alerting each other to their presence, and situating themselves within a relatively small community of practice. Instead, 24% of posts were categorized as discussions or conversations, but in a non-traditional form. Indeed, traditional conference settings encourage conversations which derive order from turn taking and referrals to previous statements, whereas on Twitter the conversation, communications, and commentaries are disrupted across a non-cohesive network in which the recipients are constantly changing. Therefore, the conversation results in a different type of participatory culture: rather than following interactions in an ordered exchange, users are placed within the multidirectional discursive space of Twitter, where they inhabit a multiplicity of conversational contexts at once. According to Ross and colleagues, users face up this disorientating context “by simply providing step by step accounts of events, in an attempt to bring some coherence and order to the backchannel” (Ross et al., 2011, p. 230).

Chaudhry and colleagues examined trends in Twitter use by physicians who attended the 2010 and 2011 annual meeting of the American Society of Clinical Oncology (ASCO), by analyzing all tweets containing the official hashtags #ASCO10 and #ASCO11. They found that the number of tweets grew from 979 in 2010 (76% of original contents and 24% of retweets) to 1477 in 2011 (52% of original contents and 48% of retweets). The authors argued that, despite the 140-character limit of the Twitter platform, during both the meetings physicians were able to discuss and debate a variety of clinical issues within tweets, such as the magnitude of survival benefits, toxicity and serious adverse event profiles, and others (Chaudhry et al., 2012). They concluded: “Within the realm of medical and academic congresses, Twitter appears to be a potentially beneficial tool for assisting clinicians to learn and instantaneously disseminate news on relevant medical advances. It may also enhance the conference experience for both on-site attendees and non-attendees, providing up-to-the-second colleague-generated commentary and perspective on breaking data, far ahead of traditional online or print news organizations covering the meeting, let alone formal peer-reviewed publication” (Chaudhry et al., 2012, p. 175).

Differently, Latierce and colleagues focused on the usage of Twitter during scientific conferences, to understand how scientific and technological information shared by researchers on Twitter can reach a broader audience. They showed that studying streams of tweets regarding scientific conferences allows identifying trend topics of the event, by combining the number of tweets posted with the conference hashtags and studying URLs, other hashtags, and retweets. Moreover, they observed that users who have an authority during an event also get a high authority score on Twitter (Latierce et al., 2010). Tweeting from a scientific conference is indeed a community-based activity. By considering the event EduCamp, held in 2010 in Hamburg, Ebner and colleagues demonstrated that this activity has limited potential in distributing or explaining conference topics, discussions or results to a broader public: “Our analysis demonstrated that the Twitter stream has a limited usefulness at this particular conference for external participants that wanted to follow the event from outside, and we conclude that our own ideas and implicit theories about the Twitter usage should be perhaps be reassessed” (Ebner et al., 2010).

3. Scientific journals on social media

As argued Kortelainen and Katvala, scientific communication can be described as a market where information is exchanged for attention (Frank, 2002). This often involves the creation and publication of free online contents: YouTube videos, a blog, research reports, photos, a Twitter stream or a Facebook page. The dynamism, diversity, and the hitherto lack of established standards and practices of Web 2.0 have favored an experimental approach, which balances the possibilities of 'open scholarship' with the often conservative practices of scholars and the limitations of existing formal scholarly communication. Thus, several scientific publishers already provide on their websites social media tools such as YouTube, Twitter, Facebook or a blog. Indeed, as claimed by Stewart and colleagues: "Apart from some major new players from outside publishing, no other types of players in the world of scholarly communication – scholarly societies, libraries, universities, funding bodies, etc. – stand out as being more motivated or better able [than academic publishers] to drive significant experimental innovation that actually gets in front of scholars in their everyday work. Academic publishers have incentives and can develop the expertise to develop and deploy new tools and services and bring them to the scholarly community. They are able to experiment over the longer term, integrating innovations with traditional services that remain in demand" (Stewart et al., 2012).

In their study of 2012, Kortelainen and Katvala investigated the use of Web 2.0 platforms by scientific journals. They found that social media tools were not commonly used by these journals and that the existing social media profiles had very varying roles: "They announce new articles, serve as discussions forums and contribute to professional knowledge" (Kortelainen & Katvala, 2012, p. 667). They found a one-way kind of communication, in which social media tools are mostly used to announce new updates and articles by RSS, on 63 of the 100 journal websites studied. 16 journals used Twitter. The number of followers of scientific journals' Twitter profiles varied between 240 and 62,747 and reflected the attention received by their websites. The ratio between the number of followed and following profiles ranged between 7.84 and 1337.33. Most of the tweets analyzed concerned new articles or blog entries. In general, in their sample social media tools were used to add information to the contents produces by the journals, some of them acting as information filters, by informing about new articles and the reader's contribution: liking, recommending, commenting, tweeting or sharing links to articles. But social media tools were also used by scientific journals to share information such as medical case reports, not reported in the form of a scientific article but still relevant for readers. Factors that seemed to attract attention to scientific journals' Twitter profiles were, according to the authors, relevance, authority, meaningfulness of contents, and interactivity. Moreover, the most attended tweets were those directed to particular audience or community. Hence, Kortelainen and Katvala concluded that "in scientific communication social media have a role of their own, complementing that of scientific journals. They give readers' views visibility and enable the publisher to publish relevant information in formats other than scientific articles. Their active use indicates the clear demand for all this. The social media strategies of the sites seem to differ e.g. with respect to user-generated content. There are sites where most of the content comes from outside the journal, and discussion e.g. on Facebook concerns relevant subjects but hardly has any connection to the articles of the journal. On other sites user participation is apparent, but the contents on Facebook, blogs or Twitter are nevertheless closely connected to the content of the journal" (Kortelainen & Katvala, 2012, p. 667).

CHAPTER 3

Visual abstracts to disseminate research on Twitter

1. What is a visual abstract?

As discussed in the previous chapter, several scientific journals have adopted social media platforms, such as Twitter, to disseminate their publications. Social media make scientific articles more accessible to readers: recent studies showed that articles featured on Twitter were three times more likely to be read, compared to those that were not (Logghe et al., 2016; Baan & Dor, 2017). Scientific journals also have adopted social media platforms as a mean to connect and share their materials on a larger scale. For example, the Twitter account of *Annals of Surgery*, the world's most referenced surgery journal, has posted more than 5.400 tweets and has more than 22.000 followers (up to January 1st, 2018), a number that dwarfs the approximately 1.300 print subscribers (Wray & Arora, 2017). But, as stated by Wray and Arora, although social media offers opportunity, there also exists a ubiquitous challenge: "In this first-paced medium, how should journals presents scientific research to an oversaturated public that is increasingly less receptive to science?" (Wray & Arora, 2017, p. e49).

In July of 2016, *Annals of Surgery* adopted the use of "visual abstracts" as a novel strategy to improve dissemination of the journal's publications. According to Wray and Arora, visual abstracts are simply visual representations of the key findings of a published scientific article or, more simply, the "movie trailer" of the manuscript (Wray & Arora, 2017). Andrew M. Ibrahim, Art Director of *Annals of Surgery* and inventor of visual abstracts, defined the tool as "a visual summary of the information contained within an abstract: similar to the abstract text of a research article, it is meant to convey the key the findings of the article in a shorter format" (Ibrahim, 2016, p. 3) **(Fig. 1)**. Importantly, Ibrahim defined also what a visual abstract is not: "Visual abstract is not a substitute for reading the article and does not contain all the details of an article" (Ibrahim, 2016, p. 3). The goal of a visual abstract is hence to inform potential readers of the main contents of a scientific article to help them decide if they want to proceed in reading the entire article.

In a broader vision, the use of visual abstracts is also an attempt to make scientific contents more accessible, without compromising the quality of the message. “I create visual abstracts to fulfil this duty, and help efficiently disseminate the best of science to a broader audience”, stated Ibrahim (Ibrahim, 2016, p. 3).

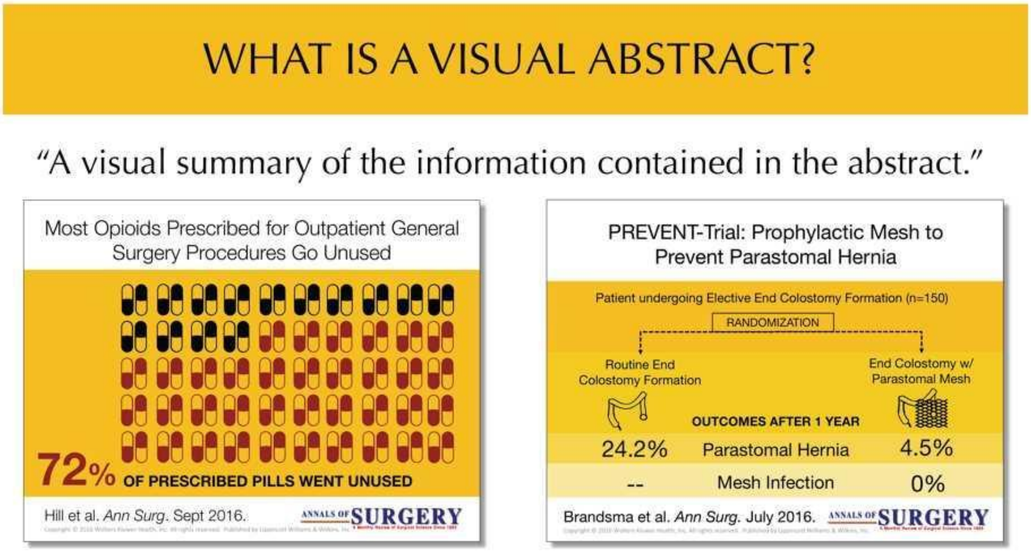


Fig. 1 Visual abstracts: definition and examples (Ibrahim, 2017).

During the last year, visual abstracts emerged as a common way to disseminate scientific research on social media. To date, more than 30 organizations, institutions, and scientific journals - including *JAMA Surgery*, *BMJ Heart* and *New England Journal of Medicine* - have adopted visual abstracts to disseminate research findings on social media. They mostly use the hashtag #VisualAbstract to summarize different contents across multiple platform including Twitter, Facebook and Instagram (Ibrahim, 2017). In addition, visual abstracts are being integrated into journal clubs, grand rounds, and poster presentations **(Fig. 2)**.

Fig. 2 Visual abstracts during conferences and poster presentations (Ibrahim, 2017).

In the second part of his document *A Primer on How to Create a Visual Abstract*, Ibrahim delineated some design principles of a visual abstract. The following are his suggestions/guidelines(Ibrahim, 2016, p. 7):

- **Focus on the user experience:** The process of design starts and always returns to the user experience. Always keep in mind, "What does my audience on Twitter want to know about scientific research?".
- **Clarity of purpose:** Particularly within complex articles, you want to spend time narrowing the key message down to what you want to deliver. Some simplification of presentation may be necessary to establish a clear focus.
- **Rapid prototyping:** There are infinite ways to visually display research. Your 1st, 2nd, and 10th visual abstract won't be your best one. You will improve significantly by rapidly trying new formats and seeing what works.
- **Iterative improvement:** Rather than ask, "Is it perfect?", design thinking focuses on, "What is the next step to make it partially better?". You will significantly improve by soliciting feedback and studying other designs.
- **Thoughtful restraint:** Prioritize the key message over completeness. Sure, having every secondary endpoint and every limitation of the article in the visual abstract is ideal to give context, but this can significantly distract from the key message. In the case of visual abstract, more is not always better.
- **Relevant creativity:** Thinking outside the box can be valuable, but ultimately need to ground in the desired outcome. Experimenting "just to be different" isn't always effective. You should frequently balance your design creativity with thoughtful restraint and clarity of purpose.

Ibrahim then reported the key components of a visual abstract (Ibrahim, 2016, p.7). Importantly, the following features make visual abstracts different from other forms of graphical abstracts or visual representations used by scientific journals **(Fig. 3)**:

- **Summarize the key question being addressed:** This usually comes from the title of the article or a heading of a key figure. Keep it short and clear.
- **Summary of outcomes:** You will need to spend time thinking about outcomes you want to present. Most articles have many more than three, so you'll have to prioritize.
- **Author, citation:** Always include at least the first author name and the year of publication.
- **State outcome comparison:** A short phrase that clearly states the outcome with the respect to groups being compared. For example, "Decreased need for blood transfusion"

is easier to follow than simply “Blood transfusions”. As much as possible, you should use the same prose used in the article for consistency.

- **Visual display of outcome:** You will want a visual that reflects the outcome you’re describing.
- **Data of outcome (Units):** In addition to stating the outcome, you will want to give the numeric representation. Be sure to include the units.
- **Who created the visual abstract:** this is often the journal, but may be an individual author. It is important not to use the logo of the journal without their permission.

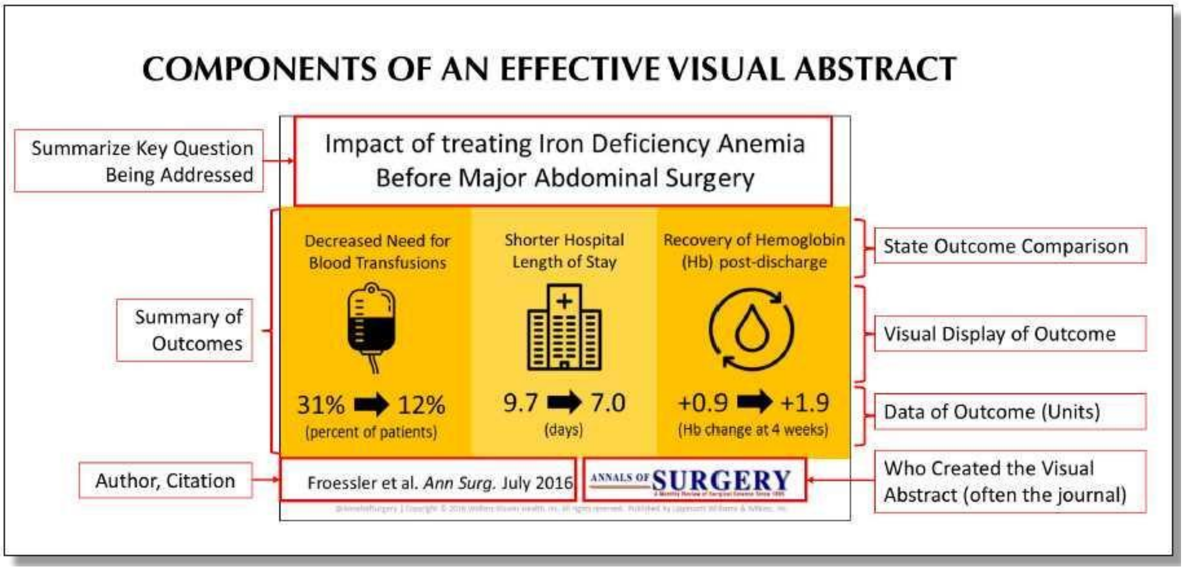


Fig. 3 Components of an effective visual abstract (Ibrahim, 2017).

According to their inventor, the use of visual abstracts has demonstrated at least three important advantages: they improve dissemination; they create a scaffold for deeper engagement, as the images are easily accessible on social media and can be integrated into round, lectures and journal clubs; they influence clinical practice, for example by communicating important practice guidelines. But the use of visual abstracts is also associated with potential perils. Ibrahim summarized those pitfalls as: over-simplification, which could mislead a potential reader about the strength of the study or implications of the findings; exacerbation of biases, for example by only reporting an interesting secondary outcome with a positive finding and leaving out that the primary outcome was a null finding; poor quality, which can undermine the potential impact visual abstracts have on disseminating scientific knowledge (Ibrahim, 2017). According to Ibrahim, the best way to avoid these potential perils is to establish standards. Importantly, he then provided a list of eight guidelines aimed at standardizing visual abstracts for scientific research and the rationale behind them (Ibrahim, 2017). Thus, a visual abstract have to:

- Clearly state the question or purpose of the study, to contextualize it.
- Describe the research design (e.g., randomized trial, retrospective review, survey) to make the quality of evidence clearer.
- Include the primary outcome of the study, to minimize reporting bias.
- Report, when appropriate, P-values or other measures of significance, to improve the reader's ability to interpret findings.
- Label citation of the article in the image itself and include a link to the full article to make the source of the data easy to locate.
- Use language consistent with the terms and definitions used in the article, to minimize "editorializing" and bias.
- Only use images for which the authors or journal have rights, in order to avoid violating copyright laws.
- Be reviewed by someone who did not create the visual abstract, to ensure credibility and identify unconscious bias.

To date, a single study investigated the efficacy of visual abstracts as a tool to disseminate research findings on Twitter. Ibrahim and colleagues conducted a prospective, case-control, crossover study to compare tweets that included only the title of the article and tweets that contained the title and a visual abstract. The study was performed between July 2016 and December 2016 and included 44 original articles published that same year in *Annals of Surgery* and tweeted by the journal's Twitter account. Half (n = 22) of the articles were tweeted as title alone and then, after a 4-week ''washout'' period, tweeted again as a visual abstract. The other half of the articles (n = 22) were tweeted using the same protocol but in the opposite order. The primary outcomes of the study were the number of times tweets were seen (impressions), the number of times tweets were shared (retweets), and the number of times articles links were clicked on (article visits), prospectively tracked using Twitter Analytics. The researchers found a strong correlation between the use of visual abstracts and increased dissemination on Twitter. When article titles were tweeted, each tweet averaged 3073.3 impressions and 11.0 retweets. However, when the same articles were tweeted as a visual abstract, each tweet averaged 23,611 impressions (7.7-fold increase; $P < 0.001$) and 92 retweets (8.4-fold increase; $P < 0.001$). Similarly, tweets with title only resulted in an average of 65.6 article visits, whereas tweets with a visual abstract averaged 175.4 article visits (2.7-fold increase; $P < 0.001$.) (Ibrahim et al., 2017). The authors concluded that visual abstracts "represent an important strategy to be considered by publishers and authors to communicate their research findings (Ibrahim et al., 2017, p. e46).

These findings are not surprising. In some way, they reflect what behavioral scientists have long understood: Humans process visual data better and faster than any other type of data. Marketing firms have long used this mechanism and have exploited humans' proclivity for visual contents to sell items or engage the audience in their narrative. Indeed, it is known that web pages with images and videos draw, on average, 94% more views than their text-only counterparts (Wray & Arora, 2017). Thus, according to Wray and Arora, "this is why visual abstracts has spread so easily to so many journals" (Wray & Arora, 2017, p. e49). However, several questions remain relevant for the future of peer-review journals. For example, the use of visual data to summarize research findings could lead to a reduction of quality and quantity of data reporting? As visual abstracts embrace social media communication criteria to reach a broader audience, the scholarly communication process could be negatively affected? What is the influence of visual abstracts on traditional and non-traditional bibliometrics?

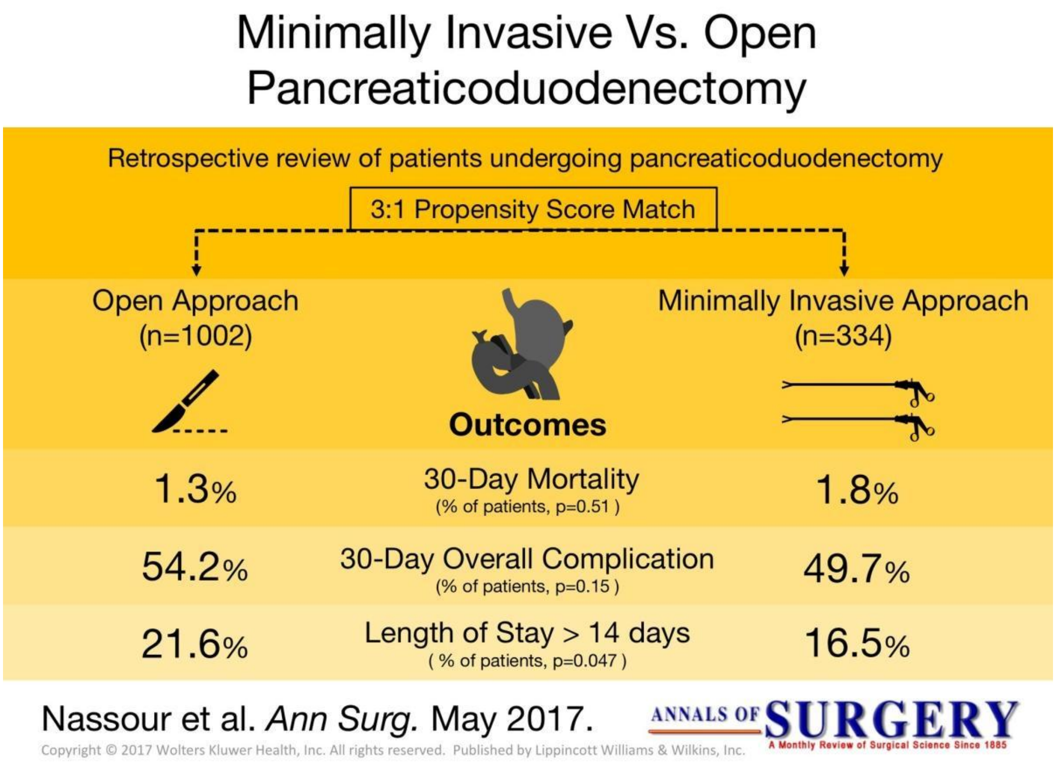


Fig. 4 Example of a visual abstract (*Annals of Surgery*).

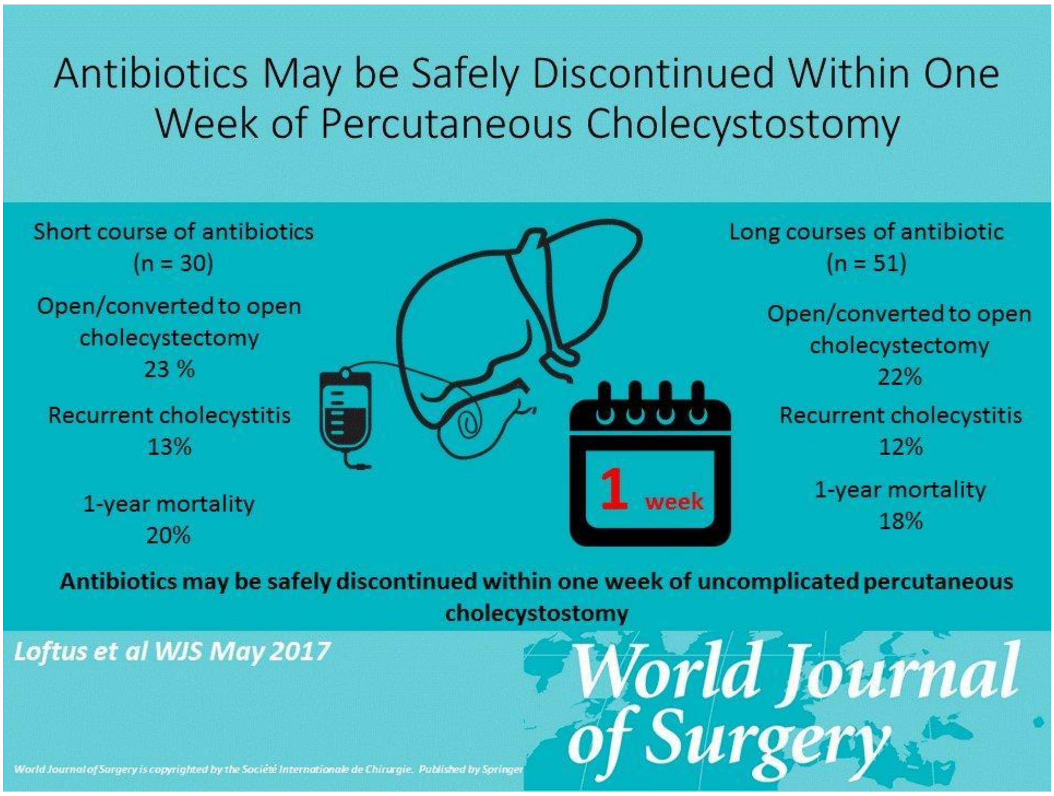


Fig. 5 Example of a visual abstract (*World Journal of Surgery*).

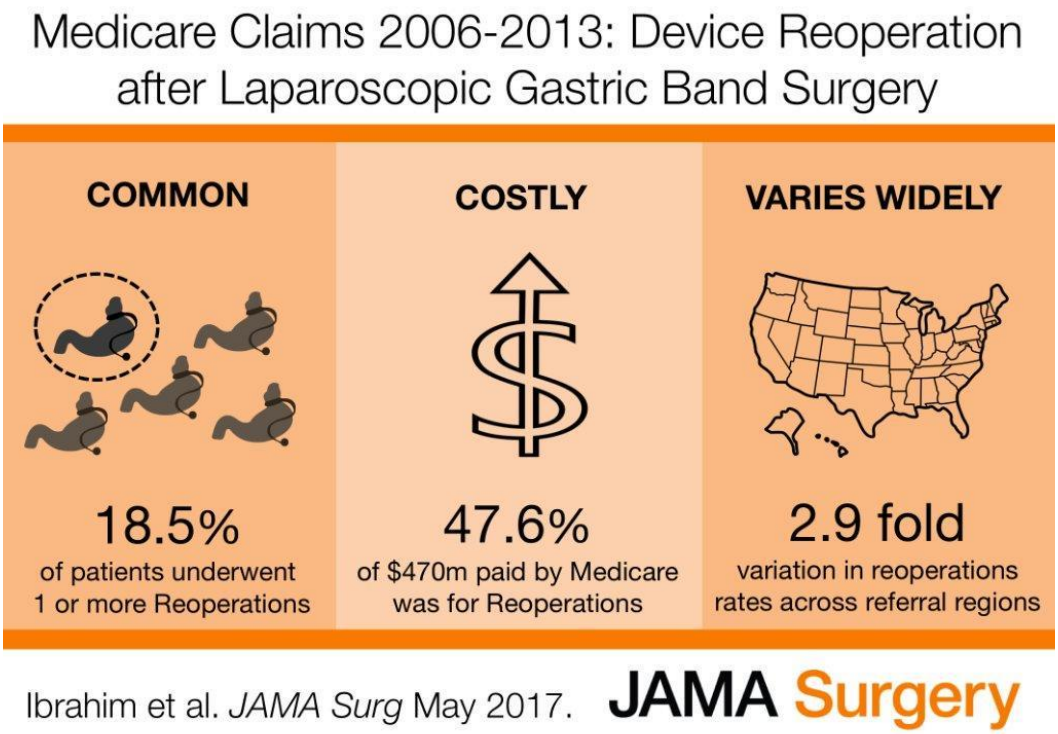


Fig. 6 Example of a visual abstract (*JAMA Surgery*).

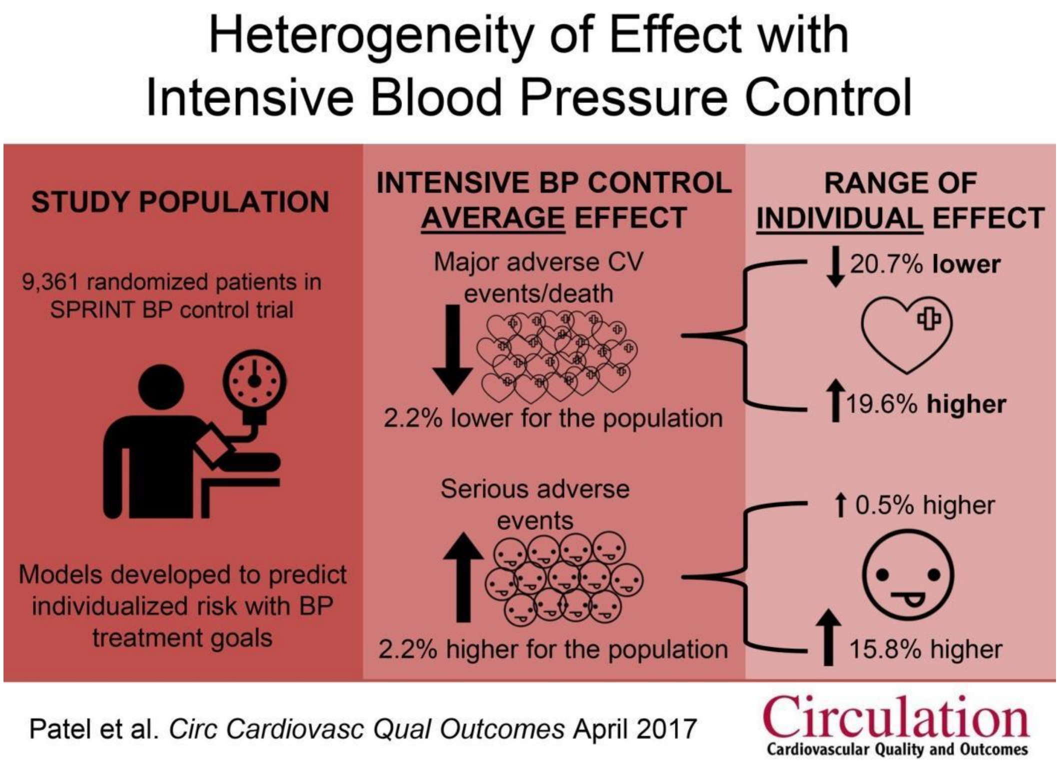


Fig. 7 Example of a visual abstract (*Circulation Cardiovascular Quality and Outcomes*).

2. Visual abstracts: Scholarly communication or social media marketing?

As stated in the first chapter, publications in scientific journal often function as a measure of scientists' competence and of the relevance of their knowledge claims. Hence, the success of a scientific article can influence a researcher's career and the credibility of a research field. Similarly, broader diffusion of scientific publications can be valuable for scientific journals, as demonstrated by the phenomenon of medialization of science. As reported in the first chapter, according to Weingart, during the second half of the 20th century science has started to adapt to the criteria of mass media communication in response to the growing demand for public legitimation. However, whereas in the context of mass media communication this phenomenon has led to a partial convergence of scholarly communication relevance criteria and so-called news values (e.g., frequency, familiarity, negativity, unexpectedness, unambiguity, conflict, continuity, and more) it is largely unknown what medialization of science may represent in the context of social media, where scholarly publishers not only share the goals of mass media communication but also the means and the spaces. Thus, to emerge and be found in the sea of countless contents published on social media, scientific journals could have started to adapt to social media marketing criteria. As previously said, one of these criteria regards the use of visualization tools, such as images, videos, and infographics as visual abstracts.

2.1. The study: Rationale

It is hence important to investigate if, and how, the use of visual abstracts may reflect this process of adaptation and if it may be associated with potential threats to scholarly communication. It is then necessary to understand where visual abstracts are positioned along the continuum between scholarly communication and social media marketing criteria. As visual abstracts are, according to the definition of Ibrahim, "a visual summary of the information contained within an abstract", the first step is to define the principal characteristics of infographics and abstracts.

Even if different opinions exist regarding what makes a good infographic, there are some fundamental agreed criteria in terms of graphical design. For example, Cairo argued that is important to select the most relevant messages and to use the least number of words to report and describe them. He also recommended to use one or two principal colours (no more) and then playing with shades, to use no more than two fonts, ideally one for the title and one for the text, and to organize the infographic in different boxes (Cairo, 2013). Concerning the elements that have to be present in the abstract of a scientific article, indications are clearer. According to the *Annals of Surgery* guidelines for authors, a structured abstract of a scientific article should report:

- one or two sentences about the objective of the study (Objective),
- a short paragraph describing the scientific context for the study (Summary Background Data),
- a statement of the plan and/or methods used in conducting the study (Methods),
- a concise summary of findings, as verified by the data (Results),
- a final a brief statement of what can be deduced from the findings of the study (Conclusions) .

Similarly, Koopman stated that an abstract has to include the motivation of the study, a problem statement, the approach, the results, and the conclusions (Koopman, 1997). According to Andrade, "the usual sections defined in a structured abstract are the 'Background',' Methods', 'Results', and 'Conclusions'; other headings with similar meanings may be used (e.g., 'Introduction' in place of 'Background' or 'Findings' in place of 'Results'). Some journals include additional sections, such as 'Objectives' (between ‘Background’ and ‘Methods’) and ‘Limitations’ (at the end of the abstract)” (Andrade, 2011, pp. 172 - 173). Adding more details, Andrade stated that - referring to clinical trials and medical research in general - the background section should briefly outline what is already known and not known about the subject related to the paper in question. The methods section should ideally include information about the research design, the clinical diagnosis of the patients included, the setting of the study (if relevant), the sampling strategy, the sample size (regarding the whole sample and the different groups), treatments received by different groups, the duration of the study, research instruments used to rate patients and the primary outcomes. The results section should include the number of patients who completed the study and the drop out rate, the results of the analysis of the primary objectives (expressed in words along with P values in parentheses), the results of the analysis of the most important secondary objectives (expressed in words along with P values in parentheses), numerical information about the analysis (e.g. standard deviation, response and remission rates, effect sizes, relative risks, number to treat), important negative findings, data on adverse events. Finally, the conclusions section should contain elements regarding the primary take-home message, the additional findings of importance and the perspective (Andrade, 2013).

2.2. The study: Methods

To answer the question about if and how, the use of visual abstracts may reflect a process of adaptation of scholarly communication to social media communication criteria - with potential threats to scholarly communication – an analysis of graphic and informative characteristics of visual abstracts has been conducted. All tweets reporting the hashtag #VisualAbstract posted between July 2016 and June 2017 have been considered. In addition to the presence of the hashtag #VisualAbstract in the text part of the tweets, inclusion criteria were: tweets with an attached infographic, tweets posted by Twitter accounts of scientific peer-reviewed journals; tweets reporting abstracts concerning papers published in the same scientific journals whose Twitter accounts posted the tweets; when a single visual abstract was posted several times, the one with the higher number of retweets has been included in the analysis. Exclusion criteria were: tweets with visual abstracts in the form of GIF images and videos; tweets with visual abstracts posted by Twitter accounts of entities different from scientific peer-reviewed journals (e.g., institutions, individuals researchers); tweets with visual abstracts not related to scientific articles.

For each tweet reporting a visual abstract, the following Twitter-related aspects have been considered: date of publication of the tweet; the number of followers of the Twitter account who posted the tweet; the number of retweets; the number of 'likes'. Regarding graphic characteristics of visual abstracts, the following aspects have been considered: number of words; number of figures (e.g., images, icons, clip-arts, graphics); number of colors and shades; number of fonts; orientation of the narrative structure (horizontal, vertical, mixed). Regarding the informative power of visual abstracts, the following aspects have been considered: the presence of some BACKGROUND information (e.g., objectives, state of the art); the presence of information regarding the METHODS of the research (research design; sampling method; total sample size at the beginning of the study; subgroups size; study duration; considered parameters); the presence of information regarding the RESULTS of the research (findings; total sample size at the end of the study; negative results; P values; other statistical parameters); the presence of CONCLUSIONS (e.g., take home massages, perspectives). Regarding the scientific value of the articles analyzed, the following parameters have been considered: impact factor of the scientific journals which published the paper; number of times the scientific article was cited in other papers (based on citations on Google Scholar); Altmetric value (when reported).

Visual abstracts have been divided into four subgroups, based on an 'informativeness index' which considered the presence of information regarding the fundamental parts of an abstract of scientific paper: BACKGROUND, METHODS, RESULTS and CONCLUSIONS (Annals of Surgery, Online Submission and Review System; Andrade, 2013; Koopman, 1997). To each visual abstract a score between 1 and 4 has been assigned. A score of 1 has been assigned when the visual abstract reported information about a single part of the four considered (e.g., only the RESULTS, only the METHODS); a score of 2 has been assigned when the visual abstract reported information about two aspects, a score of 3 has been assigned when the visual abstract reported information about three aspects, a score of 4 has been assigned when the visual abstract reported information about all four aspects. Notably, visual abstracts have been considered reporting information about METHODS when at least one of the information considered (research design; sampling method; total sample size at the beginning of the study; subgroups size; study duration; considered parameters) was reported. Similarly, visual abstracts have been considered reporting information about RESULTS when at least one of the information considered (findings, total sample size at the end of the study; negative results; P values; other statistical parameters), was reported. Nonparametric statistical analyses have been conducted to investigate if the four groups differ statistically in terms of retweets, ‘likes’, number of words, number of figures, number of colours, number of fonts, Google Scholar citations, Altmetric values.

2.3. The study: Results

A total of 158 visual abstracts have been included in the analysis. The use of this visual tools increased during the study, both in terms of tweets and of Twitter accounts using it: nine visual abstracts have been posted by two scientific journals Twitter accounts in July 2016, whereas 16 visual abstracts have been posted by nine scientific journals Twitter accounts in June 2017 (with a peak of 31 visual abstracts posted in March 2017 and a peak of 13 Twitter accounts which posted visual abstracts in April and May 2017) (Fig. 8).

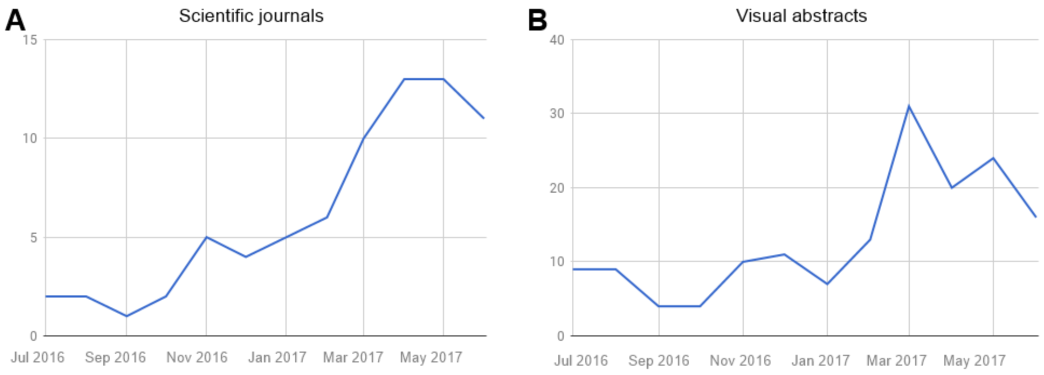


Fig. 8 Number of scientific journals that adopted visual abstracts (A) and number of visual abstracts tweeted (B) between July 2016 and June 2017.

All visual abstracts considered have been tweeted by a total of 24 scientific journals’ Twitter accounts, all operating in the field of medical research (surgery: n=11, 45.83%; general medicine: n=3, 12.5%; urology: n=2, 8,33%; nephrology: n=2, 8,33%; cardiology: n=2, 8,33%; disease of the colon and rectum: n=1, 4,17%; vascular medicine: n=1, 4,17%; social science and medicine: n=1, 4,17%; spinal disorders: n=1, 4,17%). The journals were characterized by an average impact factor of 4.295 [1,276 – 8,980] (one journal - Michigan Journal of Medicine – has been excluded from the analysis because the impact factor value was not available),.Their Twitter accounts had on average 6256,3 followers [55 – 22,400]. Visual abstracts have been retweeted on average 38 times and got 36 ‘likes’. Original studies had on average 3.2 [0 – 154] citations on Google Scholar (four studies were not available on Google Scholar) and were characterized by an average Altmetric value of 105 [1 – 1132] (80 studies did not report Altmetric values).

Regarding graphical aspects, each visual abstract averaged: 37.7 words [10 - 170], 3.33 figures [1 – 10], 2.79 colours [1 – 9], 1.12 fonts [1 – 3]. Regarding general informative aspects: BACKGROUND information were present in 10 visual abstracts (6.32%), METHODS information in 95 visual abstracts (60.12%), RESULTS information in 148 visual abstracts (93.67%), and CONCLUSIONS information in 54 visual abstracts (34.18%). More in detail, regarding METHODS, research design have been reported in 37 visual abstracts (23.41%), sampling method in 7 (4.43%), total sample size at the beginning of the study in 57 (36.07%), parameters considered in 11 (6.96%); subgroups size has been reported in 24 of 90 (26.67%) visual abstracts from studies which had subgroups, study duration has been reported in 12 of 152 (7.89%) visual abstracts from studies in which duration was a to-be-considered factor. Regarding RESULTS, total sample size at the end of the study has been reported in 64 visual abstracts (40.51%); negative results have been reported in 20 of the 43 visual abstracts from studies with negative results (46.51%), P values and other statistical parameters have been reported in 31 of 131 (23.66%) and 10 of 135 (7.40%) visual abstracts from studies which included statistical analysis. No significant correlations emerged between the number of words and retweets, 'likes', Google Scholar citations and Altmetric; number of figures and retweets, 'likes', Google Scholar citations and Altmetric. The same it's true for the number of colours and retweets, 'likes', Google Scholar citations and Altmetric and the number of fonts and retweets, 'likes', Google Scholar citations and Altmetric. On the contrary, the vertical orientation of the narrative structure of visual abstracts resulted associated with a higher number of retweets and 'likes' than horizontal and mixed orientations, even when considering the number of followers of the Twitter accounts ($P < .01$; $P < .01$).

Considering the 'informativeness index' described above, visual abstracts have been divided in 4 subgroups: Group 1 (n=44), Group 2 (n=76), Group 3 (n=35), Group 4 (n=3). Due to limited sample size, Groups 4 has been excluded from further analyses. Group 1, Group 2 and Group 3 differed significantly in term of retweets [$P < .05$] and 'likes' [$P < .05$]. Post-hoc analyses revealed that visual abstracts of Group 2 have been retweeted more frequently and received more 'likes' than those of Group 3, whereas no differences emerged between Group 1 and Group 2 [$P > .05$] and Group 1 and Group 3 [$P > .05$]. However, both differences in terms of retweets and 'likes' did not remain statistically significant when considering the number of followers of the Twitter accounts ($P > .05$). The number of words results significantly different between the 3 groups [$P < .000001$]: post-hoc analyses revealed that visual abstracts of Group 1 had fewer words than those of Group 2 [$P < .000001$] and Group 3 [$P < .000001$], whereas no difference emerged between Group 2 and Group 3 [$P > .05$]. Similarly, no differences emerged between the three groups in terms of number of figures [P > .05], number of colours [P> .05] and number of fonts [P > .05]. On the contrary, the groups differed significantly in terms of citation of Google Scholar [P < .05]: Post-hoc analyses revealed that the original studies of Group 3 (n=35) were less cited than those of Group 1 (n= 43) and Group 2 (n=74), which did not differ between each other [P > .05]. No differences emerged between the three groups regarding Altmetric values.

2.4. The study: Discussion

During the first year from their introduction by the *Annals of Surgery,* visual abstracts have been used by a growing number of scientific journals. Even if the distribution of the use of visual abstracts shows a decrease in June 2017, this may be related to a decreased use of the hashtag #VisualAbstract. Visual abstracts seem to be, at the moment, exclusively used in the field of medical research, as all the infographics included in the sample were tweeted by the accounts of scientific journals operating in the field. Particularly, the use of visual abstracts is mainly used in the research field of surgery: this is probably due to a natural diffusion mechanism which started from *Annals of Surgery* and it is now spreading in the neighbouring fields.

It is uneasy to interpret the results concerning graphic characteristics of visual abstracts. However, the average number of words, figures, colours, and fonts seem to approach the indications provided by Cairo (Cairo, 2013). These indications are nonetheless very general and, as in the case of words and images, they do not provide quantitative limits useful to compare data emerged from the present analysis. Significantly, no correlations emerged between any of these graphic aspects and diffusion/success parameters on Twitter (retweet, 'likes'), in the web environment (Altmetric) and the academic community (Google Scholar citations). Thus, even if some journal was making an effort to adapt to social media visualization criteria, it seems that this effort doesn't pay back in terms of a broader diffusion. Interestingly, the vertical orientation of the narrative structure of visual abstracts resulted associated with an higher number of retweets and 'likes' than horizontal and mixed orientations (Fig. 9, 10, 11).

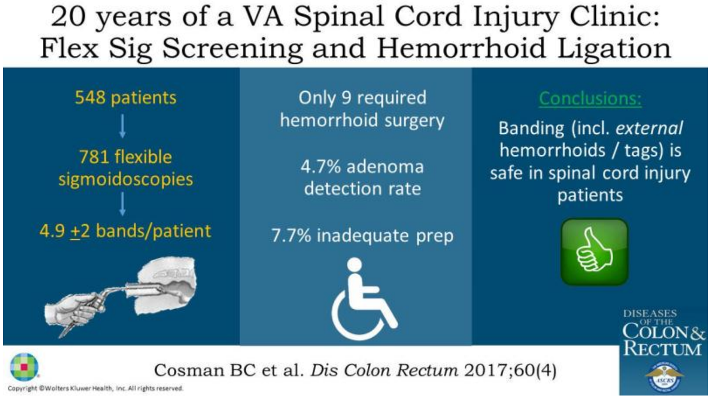


Fig. 9 Example of a visual abstract with an horizontal narrative structure.

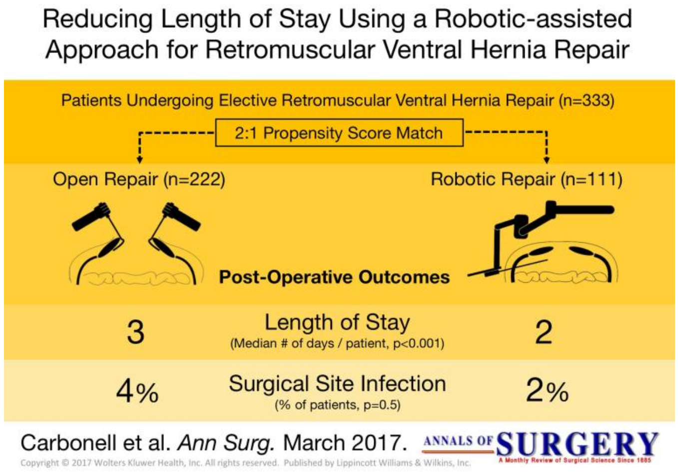


Fig. 10 Example of a visual abstract with a vertical narrative structure.

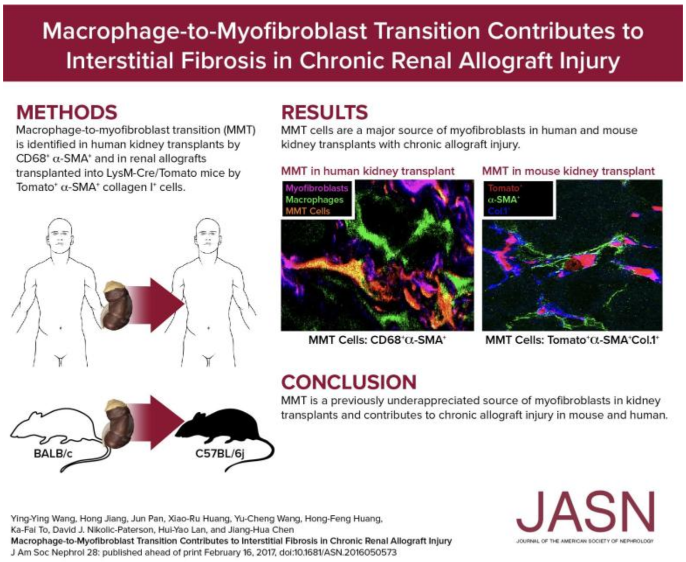


Fig. 11 Example of a visual abstract with a mixed (horizontal/vertical) narrative structure.

Adaption to social media communication criteria is more evident regarding the informative power of visual abstracts. Only three visual abstracts reported at least some information about all the four fundamental parts of an abstract: Background, method, results, conclusions. Background information (such as the objectives of the study, the state of the art in the research field) were present in 6.32% of visual abstracts, whereas conclusions were present in 34.18%. This is relevant because, as it has been described in the first chapter, scientific articles have progressively evolved to place findings in the context of current disciplinary debates and make a case for the continuing value of the authors' research program. The background section of a paper is fundamental to define a research territory and establishes a limited research problem, whereas the conclusive part is important to explain the wider significance of the initial claims, derived from having solved the research problem, and to provide suggestions on future work. As the 18th century French researcher Comte de Buffon wrote, "It is necessary to try to rise to something that is greater and more worthy of our time; it is necessary to combine observations, generalize the facts, link them through the power of analogies, and try to arrive at that high degree of knowledge where we can compare Nature with herself in her great operations, and where we can finally find ways to perfect the different parts of Physics" (quoted in Gross, Harmon, Reidy, 2002, p. 94). As a result, modern scientific articles always have a connection with theory. However, the introductive and the conclusive parts of an article seem to be often excluded from visual abstracts. This is reasonably because the authors have to select information and, understandably, they prefer to report results. Methods are not always reported too (60.12%). Again, this goes in the opposite direction of the evolution of scholarly communication, as modern scientists now always provide detailed descriptions of methods in scientific articles, in order to give weight to the quantitative results that are the products of the research. Only if the reader judges the methodological details as a plausible strategy for solving the problem, the article is interpreted as authentic science. As stated by Perelman and Olbrechts-Tyteca: "In contemporary natural [and physical] sciences, facts are increasingly subordinated to the possibility of measurement, in the broad sense of that term. The natural [and physical] sciences display a resistance to any observation which cannot be fitted into a system of measurement" (Perelman & Olbrechts-Tyteca, 1969). On the contrary, results are almost always reported (93.67%). However, questions can be raised regarding how they are reported. Indeed, P values and other statistical parameters (e.g., standard deviation) were present in 23.66% and in 7.40% of visual abstracts, respectively; similarly, negative results have been reported in 20 of the 43 visual abstracts (46.51%) and total sample size in 40.51%.

Subgroups analyses - based on the ‘informativeness index’ - showed a significant difference, in terms of retweets and ‘likes’, between Group 2 and Group 3. However, when considering the number of the followers of the accounts that tweeted the visual abstracts, differences disappeared. At the same time, it is not surprising that the three groups differed in terms of number of words, as obviously visual abstracts that reported less information also used less words to do that. Finally, the groups differed in terms of citations on Google Scholar, as the studies whose related visual abstracts were more informative resulted to be less cited. However, this effect is unlikely due to research dissemination through visual abstracts.

3. Conclusion

Results showed that visual abstracts are, at least partially, influenced by social media communication criteria. Importantly, when this form of adaption results in a reduction (in terms of scholarly communication) of the informative power of visual abstracts, it doesn’t result in a broader diffusion in the Twitter environment. Since visual abstracts which reported a lot of information are retweeted and liked similarly to those which reported less information, e.g., only methods or only results, it would be reasonable to maintain, in future visual abstracts, at least all sections that are usually discussed in textual counterparts.

A central problem is, however, that the central function of visual abstracts is not clear. Is their use aimed at communicating research findings within scientific community or at disseminating science to a broader audience? At the moment, it seems that this hybrid nature led to scarce results in both directions. Indeed, if they mean to communicate research findings they probably should be more informative and report at least the same amount of information of textual abstracts. On the contrary if they mean to communicate findings to a broader public they should be more catchy and probably not based on the structure of scientific articles. Moreover, platforms as Twitter may not be the most suitable ones to address broader audience, as it has progressively evolved as a social network used mainly by specific professional communities and not by the general public. In this sense, visual abstracts represents, at the moment, a missed opportunity.

Other important questions need to be addressed. For example, who should create visual abstracts? It seems reasonable that different professional figures may be oriented to different aims: researchers could prefer accuracy and quality of data reported, whereas editors could create visual abstracts aimed at strengthen the brand of scientific journals.

Future research should also address the use of visual abstracts on different platforms, as Facebook and Instagram, and in different contexts, as scientific conferences and poster presentations. Finally, the use of visual abstracts by individual researchers or scientific institutions should be investigated.

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