

Garfield's demon and “surprising” or “unexpected” results in science

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The relative occurrence of the words “surprising” and “unexpected” in the titles of scientific papers was 11 times more common in 2001–2005 than in 1900–1955. However, papers which had titles containing one of these words did not receive enhanced numbers of citations. Both words (and also adjectives “unusual” and “unfortunately”) are used significantly more frequently in science than in social sciences and humanities. The distribution of the statements of surprise is not random in scientific literature (chemistry journals ranked highest in the number of papers claiming “surprising” or “unexpected” results) and may reflect the level of maturity of a discipline.

Introduction

Attention of the scientific community becomes an increasingly more precious commodity [WEIGOLD, 2001; HIGGINS, 2003]. During the last 10 years, the Science Citation Index (SCI), a tool created by Eugene Garfield at the Institute for Scientific Information [GARFIELD, 1955, 2007], and now used by scientists as a database of scientific publications, has been expanding, on average, by almost 2,800 English-language scientific papers per day – an annual growth rate of 4.4%. During the first two months of 2008, the average number of publications added daily to the SCI exceeded 4,500, or one new scientific paper every 19 seconds! This flood of human knowledge, representing only a fraction of the total scientific production of the entire planet, may be

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controlled only with the help from a metaphorical entity which could be called "Garfield's demon" [JASIENSKI, 1991].

While Maxwell's demon is busy violating the second law of thermodynamics by sorting molecules, and Darwin's demon sorts genetic replicators, Eugene Garfield's citation-counting demon aims at bringing order to the world of human intellect. Its goal is to scan bibliographies of millions of academic publications, and to reveal in the patterns of citations and co-citations of papers how people think. It detects emerging frontiers of research, and ranks scientific journals, individual researchers, organizations, or even countries by their importance in the quest for knowledge [HIRSCH, 2005; BENSMAN, 2007].

Garfield's demon is not omniscient, like its Laplace's counterpart which knows all there is to know about every atom in the universe. However, Garfield's demon's limitation is by design, not out of weakness. It relies on the well-known and fundamental laws of statistics, such as Bradford's law of scattering, which claims that most of significant research is concentrated in only a small subset of sources [GARFIELD, 1980]. One may, therefore, safely avoid Laplace's demon's zeal. The public knows this approach as the "less is more" heuristic.

Finally, in contrast to Maxwell's and Laplace's demons, Garfield's demon is not a thought experiment and the SCI can be considered the product of its activity. How are then the authors of scientific publications to charm Garfield's demon and attract the readers' attention? One strategy is to make the research results more memorable through the use of such adjectives as "surprising" or "unexpected" in titles or abstracts of papers [JASIENSKI, 2006].

Methods

There were 30,133,141 abstracts of scientific papers published in English and indexed in the Science Citation Index (SCI) until February 2006. Social Sciences and Arts & Humanities Citation Indexes provided 8,151,087 English-language academic articles outside of science. As a reference point from "real life", I used the frequencies of 5000 most frequent words found in the database of 1,015,945 words created by Henry Kucera and W. Nelson Francis as The Brown Corpus of Standard American English (edict.com.hk/lexiconindex). The percentages found in SCI were compared with those in the other databases by testing the significance of log-odds ratios.

The number of citations received by 100 papers whose authors praised in the titles the surprising nature of their findings was compared with 100 papers whose authors did not. Each 'benchmark' paper was published in the same journal and issue, just next to the paper from the first group. Each paper was in English, had an abstract and, to allow over 5 years of accumulation of citations, was published not later than the year 2000. I computed the average numbers of citations for both groups (with 2 statistical outliers

removed) and compared them in a paired t-test. This method of sampling and analysis ensured that differences among disciplines and journals did not obscure the answer. If using the word "surprising" does not attract the attention of other scientists, the average difference in the received citations should be zero, across all compared pairs.

Results and discussion

Since 1900, there has been a fast increase in the frequency with which these somewhat sensationalistic words appear in the titles of scientific publications (recorded in the Science Citation Index database): from just 48 occurrences during the entire period 1900–1955 to 1660 in 2001–2005. Of course, the total number of papers published increased vastly since 1955, but the tendency among the authors to use these two words increased even faster (Figure 1). The mean annual rate of occurrence (per 100,000 papers in the SCI database) was in 2001–2005 over one order of magnitude higher than it was in the first 55 years of the 20th century (30.5 versus 2.7).

Interestingly, natural scientists use the words "surprising" or "unexpected" significantly more often than do social scientists, or authors in arts and humanities [JASIENSKI, 2006]. This is a conclusion of a study in which I searched for words indicating state of wonder and surprise in three major databases. The odds of finding in scientific literature a result or conclusion described as "surprising", "unexpected", or "unusual" are an order of magnitude greater than in standard language and several times greater than in abstracts of papers in non-scientific disciplines (see Table 1).

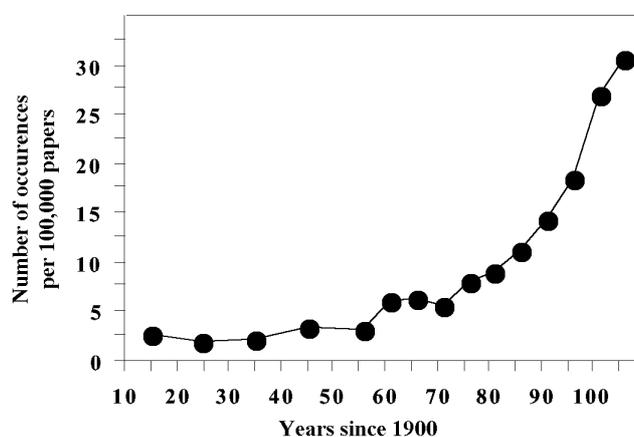


Figure 1. Relative frequency (per 100,000 published papers) of the occurrence of the words "surprising" or "unexpected" in the titles of scientific publications recorded in the Science Citation Index database in the years 1900–2005

Table 1. The number of times by which the odds of encountering a given word in natural sciences differ from the odds observed in non-science academic publications (social sciences, arts & humanities) and in standard English. All odds ratios (shown here not transformed) are highly significant ($p < 0.001$)

	In natural sciences the word in the left column is:	
Surprising	1.3 times more frequent	12 times more frequent
Unexpected	2.2 times more frequent	39 times more frequent
Unusual	7.6 times more frequent	46 times more frequent
Happy	3.6 times less frequent	1.5 times less frequent
Unhappy	7.1 times less frequent	3.7 times less frequent
Ugly	5.3 times less frequent	3.3 times less frequent
	than in social sciences, arts & humanities	than in standard English

The reverse is true in the case of the words one should not expect often in scientific abstracts, such as "happy", "unhappy" or "ugly": they occur with frequencies that are expectably and significantly lower than those characterizing either real world English or social sciences, arts and humanities. Science shows her stern face, frowning even upon such innocent words as "lovely", which appears much less frequently in science (0.00001%) than in standard language (0.0043%; log-odds ratio 3.648, $p < 0.001$).

Boring or predictable results are more likely to be underemphasized in the abstracts, although an author may also be tempted to point out that the predictions or expectations were borne out by the results. Academic machismo may clearly affect the results of my survey: exclamations of disbelief and surprise should probably be much more frequent than they are. On the other hand, striving for media attention by overstating the level of astonishment brings frequencies of appropriate adjectives into a steady state equilibrium [GOLDBERG & HELLWIG, 1997; MURRAY & AL., 2001].

Are "surprising" findings important?

Is announcing a finding as "surprising" a profitable marketing strategy for scientists, i.e. is the result of greater interest to the scientific community than results deemed 'expectable' by their researchers? If the authors' astonishment is only a reflection of a struggle with their own misunderstanding of nature, then such papers are unlikely to open new horizons for research, and, therefore, to be of interest to others. In other words, Garfield's demon is unlikely to notice a flurry of citation activity surrounding papers advertising misguided or premature reactions. In contrast, if the authors' expressions of surprise reflect truly meaningful 'twists' in Nature, such papers should be noticed by other researchers and should spawn more research.

Since the number of citations received by a paper is the best index of that interest, I asked if using the word "surprising" increased the number of paper's citations, as recorded in the SCI. The scientific community did not allow itself to be manipulated by the ploy of using such a promotional trick in the titles: the average number of citations received by papers with or without the word "surprising" was virtually the same (on

average 14.8 citations per paper; $t = 0.7$, $df = 97$, $p = 0.5$). The observed trend of increasingly frequent usage of the word cannot, therefore, be accounted for by the nonexistent benefits (citations and recognition) the authors were, presumably, hoping to derive from such usage.

There were two papers out of 32,731,340 (in March 2008) which used both the words "surprising" and "unexpected" in their titles. One of them [POIZAT, 2001] was cited 6 times. The other paper received no citations since its publication in 1993 and I am not going to break this trend here (thus keeping it on "the road to scientific oblivion", safely within the domain of *Index Oblivionis* – see [GARFIELD, 1971, 1974]). This represents just one of the many disappointments brought about by scientific research (for an example from biology see e.g. [JASIENSKI & AL., 1998]). One may find that the odds for natural scientists of using the word "unfortunately" are significantly greater than for social scientists, humanists (1.6 times more), and non-academic authors (14 times more) [JASIENSKI, 2006], and this number does not even include grant and manuscript rejections – a main source of melancholy in science [CICCHETTI, 1991; MILLER, 2006; MARSH & AL., 2007]!

Are some disciplines more surprising than others?

There were 1584 English-language papers that used the word "unexpected" in their titles (recorded in the Science Citation Index for the years 2001–2005), published in 689 scientific journals. Not surprisingly, and in agreement with a well known Bradford's law of scientometrics [BROOKES, 1969; GARFIELD, 1980], as many as 25% of all the papers (392 papers) were published in only 15 (2% of all) journals.

Unexpectedly, however, top 11 journals in the list, and altogether 41 out of top 50 journals, are in the field of chemistry (and related areas, such as biochemistry)!

The top five journals which published the most "unexpected" findings were: *Tetrahedron* and *Tetrahedron Letters* (82 papers in 5 years, or 0.5% of all papers published by these two journals during this period), *Organometallics* (41 papers, or 1% of all papers published in this journal), *Journal of Organic Chemistry* (39 papers, or 0.55% of its papers), *Chemical Communications* (37 papers, 0.5%), and *Journal of the American Chemical Society* (33 papers, 0.2%). In a similar survey of the 424 occurrences of the word "surprising" in the titles of papers published in the years 1900–2005, top 8 journals (out of 278) with the most papers reporting "surprising" findings, were also in chemistry.

A "surprising" measure of a discipline's maturity

Why are chemists so easily surprised by the results of their research? Does chemistry focus on an inherently more surprising side of Nature than do other natural

sciences? I suggest that this observation reflects a relative conceptual poverty of chemistry as a science. The pattern of the usage of certain words may provide insights into the internal importance of a discipline's own theories as drivers of empirical research. High number of exclamations of surprise and unexpectedness could be a simple index of the discipline's immaturity, when the theoretical side lags behind the empirical. As a result, awestruck empirical researchers cry "surprise", because they lack a comprehensive framework within which to interpret their findings.

Progress in experimental chemistry often relies on improvised (and often automated) mixing of compounds, free from the rigid constraints of theory. Combinatorial drug discovery or search for superconductive, magnetoresistant or luminescent materials operate on this principle [DANIELSON & AL., 1997; GEYSEN & AL., 2003]. When theory sleeps and unsupervised playing in the chemistry laboratory is allowed, then serendipity rules and research abounds in "unexpected" outcomes and "surprising" discoveries. Chemistry closes a circle and meets her older sister, alchemy.

In contrast, biologists operate within the domain of a powerful and comprehensive theory of evolution, which comprises both deterministic (natural selection) and stochastic (e.g. genetic drift) explanations. Consequently, even the most bizarre (in our judgement) biological phenomena can be explained away. Even if no satisfactory explanations can be proffered, such phenomena would probably not be dubbed "surprising". Instead, they would yield a crop of *ad hoc* hypotheses, even though those may sometimes be condescendingly referred to as "just so stories".

Counting word occurrences may therefore yield more than sociological observations about the scientists' behavior [LEWISON & HARTLEY, 2005]. It may allow us insight into philosophy of science, potentially even revealing the machinery of the scientific process [JASIENSKI, 1996].

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