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The Competition for Attention and the Evolution of Science

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Abstract

Whenever the amount of information produced exceeds the amount of attention available to consume it, a competition for attention is born. The competition is increasingly fierce in science where the exponential growth of information has forced its producers, consumers and gatekeepers to become increasingly selective in what they attend to and what they ignore. Paradoxically, as the criteria of selection among authors, editors and readers of scientific journal articles co-evolve, they show signs of becoming increasingly unscientific. The present article suggests how the paradox can be addressed with computer simulation, and what its implications for the future of science might be.

Keywords:
Attention, Competition, Evolution, Information, Production, Consumption

The competition for attention and the evolution of science

1.1 The methods of science are logical. The progress of science is not. Scientific methods prescribe how we investigate phenomena, but they do not prescribe which phenomena we investigate. The choice of phenomena and the questions we ask about them depend at least as much on psychological, sociological, political and economic factors as they do on merely logical ones. Graduate students choose a thesis topic as much because of their interests and advisor's encouragements as because Boolean algebra drives them to their choice. Scientists bend their research questions to fit government funding priorities or editorial fashions as much as to fit the trajectories of their curiosity. Lines of research end less often when questions are answered than when boredom prevails.

1.2 Historians, sociologists, economists, and psychologists who study scientific activities have long recognized the importance of personal and interpersonal influences on the development and trajectories of science (for example, see Diamond, 1996; LaTour, 1987; Merton, 1973; *Social Studies of Science*). We propose that the manifestations of these influences are in turn influenced by a small set of principles regarding the nature and limits of human attention, and by the competition for attention these principles imply. Below we present some of the most relevant principles, then discuss how their competitive consequences might be studied in simulations.

Some principles of attention

2.1 *A definition of attention*. Among the many ways of defining attention, the one we find most fruitful is inspired by two metaphors used in common speech: paying attention and spending time. Attention can be defined as what we "pay" to convert information into knowledge and knowledge into information - to convert the signals and symbols outside our head into mental representations, and to convert mental representations into signals and symbols outside our head. Opportunities to convert information to knowledge occur when we listen, watch, read, think, learn. Opportunities to convert knowledge to information occur when we speak, act, write, think, teach. Most of us spend most of our lives paying attention to pursue these opportunities. Most scientists do it for a living as well.

2.2 *Attention is a finite and nonrenewable resource*. Attention takes time, so in order to pay attention we must spend time, including the time we spend to inform and to be informed. Cosmic time may be infinite, but a lifetime is not. It is instead a limited and nonrenewable resource. Someone born today can expect to have about 80 years of time to spend, which is about 29,220 days or

701,280 hours. A dedicated scientist working, say, an average of 50 hours a week, 50 weeks a year, for a 40-year career will blow about 100,000 hours in the role, or about 14% of his or her lifetime. Most scientists spend part of this time converting new, printed research information into knowledge; this is known as keeping up with the literature. Part of the time is spent converting new research knowledge into printed information; this is known as publishing or, as Winston Churchill might phrase it, creating the literature up with which others must keep.

2.3 *Attention is selective*. While most of us can walk and talk at the same time, we cannot accomplish the same feat for intellective tasks; we can pay attention to only one intellective task at a time. None of us, for example, can write one research article with the left hand while writing another with the right, nor can we read two research articles simultaneously, nor can we deliver one lecture while listening to another, nor can we attend two meetings at once. The best we can do is to divide our attention by dividing our time between two or more tasks, and only if we have the time to divide. For better or worse, whenever we pay attention to one intellective task, we must ignore others. This means that we must frequently choose what we attend to and what we ignore, often hundreds of times each day.

2.4 Our choices of what to attend to and what to ignore define *selective attention*. The criteria for selection are numerous and complex. We tend, for example, to attend to unusual (contrasting) or unexpected (surprising) but interpretable (meaningful) stimuli, and to ignore the rest. This is why yesterday's news captures less attention the second time around, and why most of us do not pay much attention to foreign language websites we do not understand. Most scientists are trained to pay their attention to producing and consuming true and important information rather than false or trivial information. These criteria, however, are not inborn. Scientific writings do not immediately capture the attention or imagination of those unblemished by scientific training. Comparisons of the relative popularity of fiction over science, or of psychology over physics, suggest that most people employ criteria other than truth and importance when selecting what to attend to and what to ignore.

2.5 *Attention is contagious*. Social influences are among the most common in directing our attention. We tend to attend to what others attend to, or what they tell us to do. It is probably part of our instinct for social comparison and mimicry; only by paying attention to others can we learn from their trials and errors. Social influences on attention are found in the child's game of *Made you look!*, and in the crowds that gather to glimpse at what others are seeing. They can also be found in the agendas for meetings (the order of topics to attend to), in the opinions of films viewed by others, including censors, in the assignments given by teachers or in their pleas for students to pay attention to what should be learned.

2.6 The result is often a contagion of attention, a snowball effect that draws the attention of many to the information attended to by a few. The contagion is often fruitful when the information is true, important or otherwise worthwhile; people who pay attention to others running from a building yelling "Fire!" benefit from the news. But when the information is false, trivial or otherwise worthless, the contagion of attention can be pernicious. False rumours tend to waste attention; a few of them destroy lives. So too do overstated claims of medical miracles promulgated by bad journalists and their readers.

2.7 *Attention is invested in expectation of emotional returns*. Attention is governed as much by emotion as by cognition. We tend to pay attention to information that arouses us, and cease to pay attention as habituation causes the arousal to subside. Information that captures our attention we call exciting, stimulating or interesting. Information that ceases to capture our attention we call boring. When given a choice to attend to exciting or boring information, most of us choose the former.

2.8 Emotion plays as much of a role in directing the attention of scientists as it does of any other mortal. Science is an acquired taste, like the taste for cricket or opera. Those who acquire it can become quite excited by consuming and producing scientific information; it is their reward for attention paid. Some of this excitement, the intrinsic parts, comes from the information produced and consumed. Few scientists do science hoping to be bored.

2.9 And few scientists do science wishing to be ignored. Many scientists may be shy, but they still give talks at conferences, and submit manuscripts for publication, Rare is the scientists who feels shame when a talk or manuscript is cited by peers and praised. The emotional arousal of professional recognition, of the attention of peers, is a powerful intoxicant and strong influence on how much attention is paid to producing research (see Derber, 2000). Scientists who receive the recognition of their peers tend to invest more of their attention to produce more science. Those who do not receive this recognition tend to withdraw their attention and invest it elsewhere.

2.10 *Attention can be divided among people as well as within them*. As anyone who keeps a To Do list knows, demands for our attention often exceed the attention available. We sometimes try to adapt by becoming more efficient, learning to meet more demands within our attentional limits. At least as often, however, we make use of our social nature, asking others to pay their attention for meeting our demands, usually in exchange for a promise to reciprocate sometime in the future. Some call it doing a favour. Some call it division of labour. We call it the *social partitioning of attention*.

2.11 Scientists have a long history of socially partitioning their attention, relying on the attention of one another to make science work. Research assistants traditionally pay attention to tasks that researchers have no time or desire to attend. Publishers pay attention to details of printing and distributing so scientists need not distract themselves from their primary tasks. Editors, reviewers and granting committee members pay attention to culling scientific manuscripts or research proposals so other scientists need not pay attention to this thankless and often tedious task. Scientists who write manuscripts add a title to assist prospective readers in deciding with just a few seconds of attention whether or not they wish to invest attention in reading the abstract, which in turn is written to assist readers in deciding in a minute or two whether to invest more attention in the manuscript itself.

2.12 The partition of attention in these traditional ways seems to have served science well. Will it continue to do so? If not, why? And what is likely to replace it? We believe answers to these questions can be found by examining what happens to attention and its traditional partitioning as science continues to grow. And we believe the most fruitful way to address the question is by computer simulation.

The growth of science

3.1 Thanks largely to the greatest scientific invention of the 20th century: the research grant, scientists have multiplied, their tools of production have proliferated, and their rate of publication has shown exponential growth. Millions of manuscripts now come off scientific assembly lines each year, all written in hopes of being read and cited. Few are, and their proportion becomes smaller as their number increases from year to year. There is simply not enough attention to go around. As implied by its limits, attention does not expand to accommodate the proliferation of available information. Instead, more information is ignored to accommodate available attention.

3.2 Whenever the amount of information produced exceeds the amount of attention available to consume it, a competition for attention is born. Many scientists would argue that such competition is a good thing because it affords us the luxury of separating inferior science from superior science, however defined, and paying attention only to the superior stuff. Alas, this presents scientists with a paradox: someone must pay attention to all the stuff, superior and inferior, in order to make the separation. If every scientist did so, no scientist would have spare attention to produce more science; but if more science were not produced, there would be no opportunity to separate the good from the bad.

3.3 Most scientists resolve this paradox by invoking the social partitioning of attention. The result is called *peer review*. A few scientists are selected to focus their attention on the tasks of deciding which research proposals are most worthy of funding, which manuscripts are most worthy of publishing. By doing so, these peer reviewers free other scientists from the attentional demands of deciding for themselves. The reviewers normally invoke criteria related to truth and importance, providing assurances to remaining scientists that the research funded or published is the most scientifically meritorious of the lot. It is an important gatekeeping task, which is why most peers selected for it are drawn from the senior scientific establishment.

3.4 Alas, there is considerable evidence that peers show considerable disagreement about the merits of research proposals and manuscripts. Recent studies of the grant reviewing process have shown, for example, that inter-peer agreement sits stubbornly at about r = +0.50 regardless of the scientific discipline (Thorngate, Dawes & Foddy, 2009). This might be sufficient in small competitions where differences between the best and the worst proposals or manuscripts are patently obvious. But it becomes exceedingly troublesome when dozens or hundreds of proposals must be vetted and when the differences between serious contenders are small (Thorngate, 1988).

The editor's dilemma

4.1 Consider, for example, a journal editor who has enough pages to publish 40 articles each year. When the editor's journal is new and relatively unknown, it might attract 100 manuscripts each year, many previously rejected from more established journals. The range of merit of these 80 submissions is likely to be wide; perhaps 20 will be excellent, 30 will be good, and the rest will fall below. Even with fallible judgments, the 40 manuscripts published would almost certainly include almost all of the 20 excellent ones and most of good ones; it is highly unlikely that many of the lower quality manuscripts would be published. In addition, the high acceptance rate (40%), in turn, would almost certainly attract more submissions in subsequent years.

4.2 What might happen in a subsequent year when the editor still could publish only 40 articles but had 500, rather than 100 manuscript submissions? If the proportions of excellent and good manuscripts remained the same, their number would increase fivefold. So, instead of 20 excellent and 30 good manuscripts, 100 excellent and 150 good manuscripts would sit on the editor's desk. What is an editor to do? Even if editorial judgments were infallible and all published manuscripts were excellent, 60% of the excellent manuscripts would not be published, and none of the good ones would be. With fallible judgments, at least 60% of the excellent manuscripts would not be published, and some of the good manuscripts would be.

4.3 Several consequences usually follow. Editors, for example, typically escalate their criteria in order to make increasingly subtle distinctions among the surfeit of excellent manuscripts. Where once, for example, only truth and importance mattered, now truth and importance and topicality, cogency, theoretical exposition, sample size, replication, manuscript length, faddish methodologies, omnivariate statistical procedures, and reputation the senior author might emerge from the shadows in making finer distinctions among the excellent submissions. Such additional criteria would likely have disqualified most of the excellent manuscripts of generations past -- the manuscripts that likely lead past generations of scientists to tenure and editorships.

4.4 *The mimetic confound*. Many authors seeking manuscript acceptance are likely to read the published manuscripts to learn what made them acceptable, then mimic the winning formula. As a result, editors would soon face not only an increase in the average quality of manuscripts but a decrease in manuscript variability. The decrease would make new generations of manuscripts increasingly similar, and the job of choosing among them increasingly difficult.

4.5 What to do? We cannot condemn editors for doing what worked before: adding or escalating criteria to make even more subtle

distinctions among the new surfeit of excellent manuscripts. But where does it end? The added criteria can be as arbitrary as convenience will allow. How about publishing only manuscripts supported by government funding, or only those using nonlinear, hierarchical path analyses on data from at least one thousand participants measured no fewer than 12 times over at least five years in seven or more cultures around the world? Such criteria would likely truncate the number of manuscripts submitted, easing the strain in editorial attention. At the same time, they would silence the scientists with shallow pockets or small grants, or with insufficient attention to invest in administering such three-ring studies (see, for example, Thorngate & Hotta, 1995).

4.6 It is safe to assume that the number of fair criteria for judging the scientific worth of manuscripts or grant proposals is relatively small and soon exhausted. When it is exhausted, what criteria remain? If no more fair criteria exist to distinguish winners from losers, unfair criteria prevail. Their use is as likely to have more implications for authors than for editors. So it is prudent to consider some of the answers from an author's perspective.

Authors

5.1 Most editors like to publish the best manuscripts they receive for review, which leads them to an aversion to *errors of inclusion* -- publishing inferior articles. Unless editorial judgments are perfectly infallible, and sadly they are far from it, the only way to ensure that inferior articles are never published is to publish no articles at all. Ranking just above this nihilistic strategy is the conservative one: be cautious by setting high standards of acceptance, meaning numerous criteria with high cut-off points. But the mathematics of error ensures that, while high standards decrease the number of inclusion errors, they also increase the number of *exclusion errors* -- not publishing superior articles. In addition, the rate of exclusion errors increases far faster than the rate of inclusion errors as the number of submitted manuscripts increases (Thorngate, 1988; Thorngate & Carroll, 1987).

5.2 Although editors arguably suffer more from inclusion errors than from exclusion errors, the reverse is true for authors. The warm glow most authors feel when a manuscript is rejected is not an expression of accomplishment but of anger. Editors might argue that most authors have an inflated sense of their manuscripts' worth, or that the gems in their reject pile will surely be published elsewhere. Many authors might even accept the argument; some of them, including some very talented and creative researchers, might even leave science for more rewarding vocations. There will always be, however, a small group of talented, outspoken, rejected authors unwilling to accept editors' judgments or rationalizations. The small group will grow in direct relation to the number of omission errors that accumulate as the number of rejections grows. As the group multiplies, so too will the chances of a critical incident, a tipping point, that starts a revolution.

5.3 The tipping point often seems to occur when editors adopt judgment criteria related to content rather than quality. A new editor, for example, who takes the reins of a journal that traditionally publishes articles in areas X, Y, and Z might be unable to resist the temptation to reduce submissions by, for example, sacrificing areas X and Y in order to concentrate on Z. One personal benefit would likely be a considerable savings of the editor's limited attention. One social cost would surely be outrage among scientists wanting continued access to the attention of readers interested in X and Y. This is, we believe, why most new journals are born. And with their birth comes the fragmentation of scientific discipline.

5.4 Not all editors are obsessed with avoiding errors of inclusion; many are concerned with errors of exclusion as well. Editors wishing to reduce the number of excellent but unpublished manuscripts are sure to consider publishing more of them. This can be done in two ways: either by adding more pages to the journal or by shortening each article so more may be fitted into existing space. Adding pages to paper journals is costly and must be repeated in parallel with the growth of excellent manuscripts. To keep costs low, shortening manuscripts is often preferred. The preference is reflected in the *Publication Manual of the American Psychological Association* which frequently adjusts its rules to encourage economy of expression and space. Internet journals reduce the pressure to squeeze more into a fixed space; in theory, Internet journals can expand their pages indefinitely at minimal monetary cost. There is a larger cost, however, in the attention required for editors and their assistants to review all the extra pages, and for readers to ingest and digest all the science that comes their way.

Readers

6.1 Scientists devote their attention to producing information constructed with scientific methods. Editors of scientific journals devote their attention to selecting from this information the subset they judge to be sufficiently true and important for distribution to readers. Readers, however, do not read all science or only science just because it is there. The massive and expanding volume of scientific information available to prospective readers ensures they must be highly and increasingly selective in their attentional choices (Thorngate & Plouffe, 1987). How do readers make these choices? If the millions of published alternatives are, thanks to scientists and editors, prescreened for truth and importance, what criteria remain to distinguish them? We can think of two: *personal and social interest*.

6.2 Interest is, by definition, closely linked to attention. Interesting information draws or captures our attention; boring information does the reverse. What makes some information interesting and some not? James (1884), Dewey (1913), Tomkins (1962) and others argue that interest is the attentional consequence of emotional arousal, suggesting that interesting information holds our attention by stirring the chemistry of our brain. Berlyne (1960) proposed four variables governing curiosity, a close cousin of interest: novelty, complexity, uncertainty and conflict (see also, Davis, 1971). Each of these variables describes a relationship

between information and the people who attend to it; interest is not an intrinsic property of information, nor is it a universal response from consumers of information. There are large individual differences in what people find interesting. What is novel to one person, for example, might be routine for another. What is silly for scientists might be profound for the politicians who fund them, and vice versa.

6.3 As the growth of scientific information leads editors to change their criteria for manuscript selection, so too does it lead readers to do the same. In both cases, the shifts in criteria seem analogous to shifts in strategies of selection that drive trajectories of evolution. The scientific criteria of truth and importance may increase the chances that information will survive an editorial cut. Once survival is assured, however, criteria of personal and social interest may determine how many readers attend to or use the information for how long (Thorngate, 1990a, 1990b).

6.4 Consider the colon. Dillon (1981; see also, Perry 2007) discovered that the two-dots of punctuation have been increasing in popularity among titles of scholarly journals, in part because titles with a colon stand a better chance of publication than do titles colon free. Why? We speculate that the colon allows an author to have the best of both worlds: an attention grabbing, zinger of a title on the left, followed by a sober and scholarly translation on the right, for example, "Sex and violence: A meta-analysis of the effects of food supply on the mating rituals of the brown squirrel." Of course, nothing of scientific value is gained by adding a colon to a manuscript. It does, however, give an author more license to attract attention in a highly saturated information market by appealing to personal interests.

6.5 Social interests surely play a role in readers' selections as well. Books endorsed by Ophra Winfrey or appearing on the New York Times bestseller list lead a charmed life in large part because their mention attracts attention. Journalistic reports of scientific studies, seemingly regardless of their accuracy, attract the same. So too does publication in a "high impact" journal, presumably attended to by more readers than publication in a low impact journals. In years past, publication in any refereed journal was considered an indicant of scientific success. Times have changed. Now, indicants of the attention paid to a publication predominate. Citation counts prevail. Among all the presumably excellent articles that float to the top of the publication pile, the ultimate assessment of their relative worth is now often made by counting the number of times authors have paid enough attention to cite them. In other walks of life this is called a popularity contest.

The need for simulation

7.1 The influences that authors, editors and readers of science have on one another are exceedingly complex, in part because they are governed and bounded by the limits of attention. There is much still to be learned about attention and its manifestations, but enough is known to begin constructing models of the complex relations, and to simulate what might happen to science given current trends in its production and consumption. Will science continue to fragment into an ever-increasing number of subspecialties? If so, what will happen to competitions for the limited attention of science editors and consumers? What new criteria might emerge? And what might their consequences be?

7.2 Such questions seem well-suited to be addressed by agent based modelling. Build models of authors, editors and readers. Vary the amount of attention they have and criteria they use for deciding what to attend to and what to ignore. Vary the number of authors editors and readers, and the strategies they use to compete for a greater market share of attention. Then watch what emerges.

7.3 We can foresee the emergence of at least three consequences. The first possible consequence is a rise in cheating, fabricating results in a way that will capture more attention (and citations). The rise would more likely occur as editors and their reviewers are inundated with more manuscripts, and thus less likely to pay close attention to them. It would validate an anonymous cynic, "Everybody lies, but it doesn't matter because nobody listens."

7.4 A second possible consequence is an escalation of methods of attracting interest. The colon is only one example. Marketing experts have dozens more. What about animated graphics in scientific publications? What about sound or video? Why not advertise new publications on Google to a targeted audience? Or reward those who cite a publication with loyalty points? In a world where universities advertise for students on the sides of busses, why should science be immune from tricks of the marketing trade?

7.5 A third possible consequence is boredom. If science competes for attention by becoming increasingly technical, complex and esoteric, the size and niche of its audience is bound to shrink. A single musician who repeatedly plays only one tune on one instrument soon bores the audience. A roomful of musicians playing different tunes on different instruments also soon bores the audience. It is unlikely that science will increase or even hold its audience by mimicking a roomful of musicians, but this is what might emerge from continuous escalation of the competition for attention. If it does, science as we know it may become extinct, not because it has answered most of the questions it tries to address (Horgan, 1996), but because it has addressed too many questions to sustain anyone's interest.

7.6 All three of these possible consequences would surely disappoint those of us raised on the excitement of science and the belief, however naive, that science is pure and immune from the intellectual and political pollutants of life outside the lab. Can the disappointments be avoided? Simulation might address this question too. Consider, for example, the radical but interesting suggestion for managing the growth of science that was once offered by the social psychologist, Bibb Latane (personal

communication, circa 1974). Every PhD in science should be given three tickets, one for each of three publications during her or his career. Each ticket would guarantee a publication in a high-impact journal. But once the tickets were gone, so too would be opportunities for future publications. The scheme might encourage each scientist to be very careful about the value of each publication, while dramatically reducing the collective accumulation of publications, perhaps to a level that would allow many more scientists to read what their colleagues had written. Simulations could explore the consequences of such interventions. It seems worth the effort to construct them.

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