The Scientific Method: A Need for Something Better?

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The Scientific Method: A Need for Something Better?

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Here is the last part of the triptych that started with the "Perspectives" on brainstorming that was followed by the one on verbal overshadowing. I have decided to keep this for last because it deals with and in many ways attempts to debunk the use of the scientific method as the Holy Grail of research. Needless to say, the topic is controversial and will anger some.

In the "natural sciences," advances occur through research that employs the scientific method. Just imagine trying to publish an original investigation or getting funds for a project without using it! Although research in the pure (fundamental) sciences (eg, biology, physics, and chemistry) must adhere to it, investigations pertaining to soft (a pejorative term) sciences (eg, sociology, economics, and anthropology) do not use it and yet produce valid ideas important enough to be published in peer-reviewed journals and even win Nobel Prizes.

The scientific method is better thought of as a set of "methods" or different techniques used to prove or disprove 1 or more hypotheses. A hypothesis is a proposed explanation for observed phenomena. These phenomena are, in general, empirical—that is, they are gathered by observation and/or experimentation. "Hypothesis" is a term often confused with "theory." A theory is the end result of a previously tested hypothesis, meaning a proved set of principles that explain observed phenomena. Thus, a hypothesis is sometimes called a "working hypothesis," to avoid this confusion. A working hypothesis needs to be proved or disproved by investigation. The entire approach employed to validate a hypothesis is more broadly called the "hypothetico-deductivism" method. Not all hypotheses are proved by empirical testing, and most of what we know and accept as truth about the economy and ancient civilizations is solely based on . . . just observation and thoughts. Conversely, the deep thinkers in the non-natural disciplines see many things wrong with the scientific method because it does not entirely reflect the chaotic environment that we live in—that is, the scientific method is rigid and constrained in its design and produces results that are isolated from real environments and that only address specific issues.

One of the most important features of the scientific method is its repeatability. The experiments performed to prove a working hypothesis must clearly record all details so that others may replicate them and eventually allow the hypothesis to become widely accepted. Objectivity must be used in experiments to reduce bias. "Bias" refers to the inclination to favor one perspective over others. The opposite of bias is "neutrality," and all experiments (and their peer review) need to be devoid of bias and be neutral. In medicine, bias is also a part of conflict of interest and produces corrupt results. In medicine, conflict of interest is often due to relationships with the pharmaceutical/device industries. The *American Journal of Neuroradiology* (*AJNR*), as do most other serious journals, requires that contributors fill out the standard disclosure form regarding conflict of interest proposed by the International Committee of Medical Journal Editors, and it publishes these at the end of articles.[1]

Like many other scientific advances, the scientific method originated in the Muslim world. About 1000 years ago, the Iraqi mathematician Ibn al-Haytham was already using it. In the Western world, the scientific method was first welcomed by astronomers such as Galileo and Kepler, and after the 17th century, its use became widespread. As we now know it, the scientific method dates only from the 1930s. The first step in the scientific method is observation from which one formulates a question. From that question, the hypothesis is generated. A hypothesis must be phrased in a way that it can be proved or disproved ("falsifiable"). The so-called "null hypothesis" represents the default position. For example, if you are trying to prove the relationship between 2 phenomena, the null hypothesis may be a statement that there is no relationship between the observed phenomena. The next step is to test the hypothesis via 1 or more experiments. The best experiments, at least in medicine, are those that are blinded and accompanied by control groups (not submitted to the same experiments). Third is the analysis of the data obtained. The results may support the working hypothesis or "falsify" (disprove) it, leading to the creation of a new hypothesis again to be tested scientifically. Not surprising, the structure of abstracts and articles published in *AJNR* and other scientific journals reflects the 4 steps in the scientific method (Background and Purpose, Materials and Methods, Results, and Conclusions). Another way in which our journals adhere to the scientific method is peer review—that is, every part of the article must be open to review by others who look for possible mistakes and biases. The last part of the modern scientific method is publication.

Despite its rigid structure, the scientific method still depends on the most human capabilities: creativity, imagination, and intelligence; and without these, it cannot exist. Documentation of experiments is always flawed because everything cannot be recorded. One of the most significant problems with the scientific method is the lack of importance placed on observations that lie outside of the main hypothesis (related to lateral thinking). No matter how carefully you record what you observe, if these observations are not also submitted to the method, they cannot be accepted. This is a common problem found by paleontologists who really have no way of testing their observations; yet many of their observations (primary and secondary) are accepted as valid. Also, think about the works of Sigmund Freud that led to improved understanding of psychological development and related disorders; most were based just on observations. Many argue that because the scientific method discards observations extemporaneous to it, this actually limits the growth of scientific knowledge. Because a hypothesis only reflects current knowledge, data that contradict it may be discarded only to later become important.

Because the scientific method is basically a "trial-and-error" scheme, progress is slow. In older disciplines, there may not have been enough knowledge to develop good theories, which led to

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the creation of bad theories that have resulted in significant delay of progress. It can also be said that progress is many times fortuitous; while one is trying to test a hypothesis, completely unexpected and often accidental results lead to new discoveries. Just imagine how many important data have been discarded because the results did not fit the initial hypothesis.

A lot of time goes into the trial-and-error phase of an experiment, so why do it when we already know perfectly well what to expect from the results? Just peruse *AJNR*, and most proposed hypotheses are proved true! Hypotheses proved false are never sexy, and journals are generally not interested in publishing such studies. In the scientific method, unexpected results are not trusted, while expected and understood ones are immediately trusted. The fact that we do "this" to observe "that" may be very misleading in the long run.[2] However, in reality, many controversies could have been avoided if instead of calling it "The Scientific Method," we simply would have called it "A Scientific Method," leaving space for development of other methods and acceptance of those used by other disciplines. Some argue that it was called "scientific" because the ones who invented it were arrogant and pretentious.

The term "science" comes from the Latin "scientia," meaning knowledge. Aristotle equated science with reliability because it could be rationally and logically explained. Curiously, science was, for many centuries, a part of the greater discipline of philosophy. In the 14th and 15th centuries, "natural philosophy" was born; by the start of the 17th century, it had become "natural sciences." It was during the 16th century that Francis Bacon popularized the inductive reasoning methods that would thereafter become known as the scientific method. Western reasoning is based on our faith in truth, many times absolute truth. Beginning assumptions that then become hypotheses are subjectively accepted as being true; thus, the scientific method took longer to be accepted by Eastern civilizations whose concept of truth differs from ours. It is possible that the scientific method is the greatest unifying activity of the human race. Although medicine and philosophy have been separated from each other by centuries, there is a current trend to unite both again.

The specialty of psychiatry did not become "scientific" until the widespread use of medications and therapeutic procedures offered the possibility of being examined by the scientific method. In the United States and Europe, the number of psychoanalysts has progressively declined; and most surprising, philosophers are taking their place.[3] The benefits philosophy offers are that it puts patients first, supports new models of service delivery, and reconnects researchers in different disciplines (it is the advances in neurosciences that demand answers to the more abstract questions that define a human "being"). Philosophy provides psychiatrists with much-needed generic thinking skills; and because philosophy is more widespread than psychiatry and recognizes its importance, it provides a more universal and open environment.[4] This is an example of a soft discipline merging with a hard one (medicine) for the improvement of us all. However, this is not the case in other areas.

For about 10 years, the National Science Foundation has sponsored the "Empirical Implications of Theoretical Models" initiative in political science.[5] A major complaint is that most political science literature consists of noncumulative empirical studies and very few have a "formal" component. The formal part refers to accumulation of data and use of statistics to prove or disprove an observation (thus, the use of the scientific method). For academics in political science, the problem is that some journals no longer accept publications that are based on unproven theoretic models, and this poses a significant problem to the "non-natural" sciences.[6] In this case, the social sciences try to emulate the "hard" sciences, and this may not be the best approach. These academics and others think that using the scientific method in such instances emphasizes predictions rather than ideas, focuses learning on material activities rather than on a deep understanding of a subject, and lacks epistemic framing relevant to a discipline.[7] So, is there a better approach than the scientific method?

A provocative method called "model-based inquiry" respects the precepts of the scientific method (that knowledge is testable, revisable, explanatory, conjectural, and generative).[7] While the scientific method attempts to find patterns in natural phenomena, the model-based inquiry method attempts to develop defensible explanations. This new system sees models as tools for explanations and not explanations proper and allows going beyond data; thus, new hypotheses, new concepts, and new predictions can be generated at any point along the inquiry, something not allowed within the rigidity of the traditional scientific method.

In a different approach, the National Science Foundation charged scientists, philosophers, and educators from the University of California at Berkeley to come up with a "dynamic" alternative to the scientific method.[8] The proposed method accepts input from serendipitous occurrences and emphasizes that science is a dynamic process engaging many individuals and activities. Unlike the traditional scientific method, this new one accepts data that do not fit into organized and neat conclusions. Science is about discovery, not the justifications it seems to emphasize.[9]

Obviously, I am not proposing that we immediately get rid of the traditional scientific method. Until another one is proved better, it should continue to be the cornerstone of our endeavors. However, in a world where information will grow more in the next 50 years than in the past 400 years, where the Internet has 1 trillion links, where 300 billion e-mail messages are generated every day, and 200 million Tweets occur daily, ask yourself whether it is still valid to use the same scientific method that was invented nearly 400 years ago?

REFERENCES

1. Uniform Requirements for Manuscripts Submitted to Biomedical Journals: Ethical Considerations in the Conduct and Reporting of Research—Conflicts of Interest. International Committee of Medical Journal Editors, http://www.icmje.org/ethical_4conflicts.html. Accessed October 2, 2012
2. Halwes T. The Myth of the Magical Scientific Method. http://dharma-haven.org/science/myth-of-scientific-method.htm. Accessed October 2, 2012
3. Conn JH. **The decline of psychoanalysis: the end of an era, or here we go again.** *JAMA* 1974;228:711–12
4. Fulford KW, Stanghellini G, Broome M. **What can philosophy do for psychiatry?** *World Psychiatry* 2004;3:130–35

5. EITM. Empirical implications of theoretical models. http://www.nsf.gov/sbe/ses/polisci/reports/pdf/eitmreport.pdf. Accessed October 2, 2012
6. Clarke KA, Primo DM. Overcoming the 'physics envy.' http://www.nytimes.com/2012/04/01/opinion/sunday/the-social-sciences-physics-envy.html. Accessed October 2, 2012
7. Windschitl M, Thompson J, Braaten M. **Beyond the scientific method: model-based inquiry as a new paradigm of preference for school science investigations.** *Science Education* 2008;92:941–67
8. Musante S. A dynamic alternative to the scientific method: AIBS eye on education. http://www.aibs.org/eye-on-education/eye_on_education_2009_01.html. Accessed October 2, 2012
9. Understanding science. How science really works. http://undsci.berkeley.edu. Accessed October 2, 2012

EDITORIAL

Acute Stroke Imaging Research Roadmap II and International Survey of Acute Stroke Imaging Capabilities: We Need Your Help!

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on behalf of the STIR and Virtual International Stroke Trials Archive (VISTA)-Imaging Investigators

Performing neuroimaging in the setting of a clinical trial, across multiple sites, is challenging because it involves standardizing acquisition and processing imaging protocols on multiple types of scanners by using multiple different platforms. The challenge is even more pronounced for cutting-edge imaging techniques such as arterial spin-labeling or diffusion tensor imaging. Mechanisms are therefore needed to translate and test advanced imaging methods across centers, to encourage the use of advanced imaging in acute settings, to stimulate closer academic-industry collaborations, and to promote the retrospective and prospective collection and pooling of imaging data while keeping in mind practical considerations such as clinical feasibility.

This daunting task has been tackled by the Stroke Imaging Research (STIR) group, a consortium of neuroradiologists, neurologists, imaging scientists, and emergency physicians with an interest in stroke imaging. STIR had a series of meetings in 2012 and 2013, where heated debates led to consensus recommendations as part of a stroke imaging research roadmap. This roadmap was published in *Stroke*[1] and should be read by all radiologists interested in stroke research because it contains some very important recommendations in terms of standardization of image acquisition and processing for stroke and how imaging should be incorporated in stroke clinical trials. To view the paper use the link in this issue's table of contents, or go directly to: http://stroke.ahajournals.org/lookup/doi/10.1161/STROKEAHA.113.002015.

STIR proposes a specific, standardized terminology for acute stroke imaging, aligned with the National Institute of Neurological Disorders and Stroke Common Data Elements,[2] including a modified TICI scale to assess reperfusion on cerebral conventional angiography. STIR also introduces the concept of "Treatment-Relevant Acute Imaging Targets" (TRAIT), which is meant to capture imaging elements needed for inclusion (or exclusion) into specific treatment protocols. TRAIT acts as a shorthand term to describe the collection of specific imaging metrics used in protocols and simultaneously reminds trial designers to ensure that imaging is directed to the key anatomic or physiologic targets of their specific intervention.

STIR proposes the establishment of a calibration process for measuring ischemic core and penumbral software, as well as the population of the STIR clinical and imaging data repository to facilitate this calibration process. STIR recognizes that imaging techniques continuously evolve and that there will always be a newer, better ischemic core or penumbral imaging technique or processing software. Therefore, it is desirable to find a balance between continued attempts to improve on existing methods versus determining whether existing methods are good enough to be used in current clinical trials. At this time, STIR does not assess or recommend how to use ischemic core and penumbral information for prognosis, prediction of response to treatment, and/or selection of patients for reperfusion therapy. These are better answered in well-designed clinical trials or prospective validation studies.

Finally, STIR recommends the creation of a stroke neuroimaging network involving a collaboration between sites to promote scientific collaboration and education in a distributed fashion and further advance imaging protocols and software reuse, and data and model sharing. As a first step towards the creation of this network, STIR is conducting an international survey for which we need your help. Please take 15 minutes to fill out the survey, which can be found at https://www.surveymonkey.com/s/DQRDYB2. Thank you in advance for your collaboration!

REFERENCES

1. Wintermark M, Albers GW, Broderick JP, et al. **Acute Stroke Imaging Research Roadmap II.** *Stroke* 2013 Jul 16 [EPub ahead of print]
2. http://www.ninds.nih.gov/research/clinical_research/toolkit/common_data_elements.htm Accessed July 1 2013

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EDITORIAL

Mechanical Thrombectomy after IMS III, Synthesis, and MR-RESCUE

L. Pierot, J. Gralla, C. Cognard, and P. White

Three recent publications report the neutral results of 3 randomized studies (Synthesis Expansion, Interventional Management of Stroke [IMS] III, and Mechanical Retrieval and Recanalization of Stroke Clots Using Embolectomy [MR-RESCUE]) comparing IV thrombolysis therapy with the endovascular treatment (EVT) of acute ischemic stroke (AIS).[1-3] The simultaneous publication of these 3 reports might lead to the erroneous conclusion that endovascular treatment has no place in the management of AIS. However, the role of endovascular therapy for the treatment must be more carefully considered, given the tremendous

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