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Reducing Bias in Scientific Publication through an Open Access Repository

A thesis submitted in partial fulfillment
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by

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Abstract

Heuristics (or intuitions), while quite often helpful, can lead to mistakes when they are not fit for a particular environment. As a result, heuristics can be detrimental to a scientific endeavor, where the researcher is expected to remain as accurate, impartial, and logical as possible. This tendency of individuals to use faulty intuitions is one of the main reasons for the existence of a peer-review process in academe. Due to the current system of journal publication and peer-review, however, there is a high potential for bias in scientific publishing. Researchers may be risk averse, attempting to research that which they think will receive funding and get published. "Salami-slicing" works to increase one's publication count, only publishing novel and positive results, and overselling the impacts of results have all become common practices to get ahead. Referees in the journal peer-review process may also be biased in their assessments of what research meets their standards. Journals that do not accept replication studies, articles that go against the prevailing paradigm, or experiments that do not meet the .05 statistical significance cut-off inadvertently skew the scientific knowledgebase. Possible solutions to the biases in the current system of journal publishing and peer-review will be considered, particularly the acceptance of a centralized open access repository. If researchers utilize one repository that collects all research and publishes *before* the review process, biases concerning publication may be avoided entirely and the quality of research may be assessed after the fact. Instead of one bias that is enforced, postpublication review may allow for a proliferation of paradigms to emerge. One commonly used and agreed upon centralized open access repository would also allow for new journals to arise that are more domain-specific. Such a solution would increase the speed of discovery, innovation, and greatly facilitate scientific advancement.

Acknowledgement

First, I would like to thank God, nature, or whatever force gave me the strength and good health to finish this monster. Next, I would like to express my utmost gratitude to my thesis advisor, Dr. Thomas Nickles, for making this work possible, leading by example, and guiding without directing. Finally, I am indebted to my brother for inspiring me to think freely and to care deeply about all subjects, my parents for encouraging me every step of the way, and the love of my life for giving me purpose.

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Starting the Conversation

With websites emerging that provide free access to journal articles that otherwise would require a subscription, the controversy of open access is coming to the forefront in academic discussion. Like music pirating, academic journal articles are now becoming freely and widely available through less than reputable sources. However, these open access initiatives disregard the concerns of publishers in favor of the potential benefits that open access might offer.

Websites like Sci-Hub are making it possible for anyone to access paid content for free. This sharing of content has prompted legal action by Elsevier, as the publishing company claims to have lost substantial amounts of money due to the website's existence. The journal *Nature* (news team) says, "Access to the site's web domain was suspended following the injunction. But Sci-Hub, which is advertised as a service 'to remove all barriers in the way of science', has since moved to a different domain" (Schiermeier, 2015). Since Sci-Hub was not created within the United States, it is not subject to the same laws and continues to operate under a different domain.

The website was created after Alexandra Elbakyan grew fed up with the delays associated with accessing scientific literature legitimately. "When she got back to Kazakhstan, frustration with the barriers that scientists face would soon lead her to create Sci-Hub—an awe-inspiring act of altruism or a massive criminal enterprise, depending on whom you ask" (Bohannon, 2016, p. 511). For researchers that lack access to articles due to the cost of subscriptions, Sci-Hub is commendable. For publishers who are losing money due to the existence of Sci-Hub, however, such a website is heinous.

Publishers might argue that such open access websites violate international copyright laws, but Sci-Hub has some criticisms of the publishing companies. The new Sci-Hub webpage

explains, “The Open Access is a new and advanced form of scientific communication, which is going to replace outdated subscription models. We stand against unfair gain that publishers collect by creating limits to knowledge distribution” (Sci-Hub, 2016). What the creator of Sci-Hub (Alexandra Elbakyan) believes, and all supporters of open access, is that information should not be withheld but shared.

The purpose of this work is to explore whether the traditional publication system or open access can best address the issues of bias in the scientific literature, innovation in scientific disciplines, and the funding of publishing. By looking at literature pertaining to these topics, it will be possible to determine which course of action yields the better outcomes.

To start the conversation, few would argue with the claim that individuals, including scientists, often make incorrect inferences. Some of these mistakes can be traced to the use, whether conscious or subconscious, of heuristics that produce “intuitions” or “gut instincts.” Although human beings employ heuristics successfully much of the time, such cognitive shortcuts can be detrimental to a scientific endeavor, where the researcher is expected to remain as accurate and logical as possible. The tendency of individuals to act upon incorrect intuitions is one of several reasons for the existence of a journal review process. By having peers review one’s work, the assumption is that such examination will reduce bias and improve the quality of the work.

However, owing to the current system of refereed journals, and similarly for grant applications, there is a high potential for bias in scientific publishing. Researchers are incentivized by that which they think will receive funding and lines of research that they anticipate will get published. Referees in the review process are also biased in their assessments of what research meets their standards (Lee, 2015, p. 1273). Scientific journals that publish only

stringently new work shun replication studies and experiments that do not meet the .05 statistical significance cut-off.

This biased practice inadvertently skews the scientific knowledgebase, particularly through editorial and publication biases, defined later in the chapter (see Matías-Guiu & García-Ramos, 2011, p. 2). One possible solution to problems in traditional peer-review is through open access repositories. The possible solution that I propose is creating a repository that collects all research and publishes *before* the review process. This change, I shall argue, will eliminate the aforementioned biases concerning the review and selection process, without diminishing research quality-assessment after the fact.

Science, as an objective enterprise, endeavors to eliminate bias by bringing together subjective interpretations to create objective verification. Such "intersubjectivity" constitutes one important kind of objectivity and amounts to one sort of robustness, where distinct paths of thought and practice converge on a common conclusion. Researchers individually are flawed in their assessments. A collection of many such individuals, however, can gain a sort of consensus on the existence of a fact or the value of a particular model. If a claimed fact or hypothesis has been tested and retested, each time turning up the same result, the specialist community will conclude that it is established, at least *pro tem*. Should the investigative results of one individual differ from those of others, this discrepancy might be due to a different perspective or experimental design that the individual maintained while investigating, the individual might have overlooked something that the others did not, or s/he might have noticed something that the others did not notice. In other words, objective verification is effective at corroborating the claimed existence of a fact, while discarding defective investigations.

Imagine that there are three people who were born completely blind. They simultaneously come across an object in their path one day and proceed to feel along the edges of this object. The first person feels hair, like that on a tail, and says, "It's a horse." The second person feels a tall curved object with a rough surface and says, "No, it must be a tree." The final person feels a long and rough object that can be easily moved and says, "I have no idea what any of you are thinking. It has to be a snake."

In actuality, what the three people are feeling are various parts of an elephant. If they were to trace their hands along the elephant's sides, they might eventually reach each other's hands and determine that all three of them are actually feeling the same object and not three separate objects, as they originally concluded.

This adage is largely descriptive of the way science works. Humans lack the necessary senses to properly examine all aspects of the world around them. As a result, much of our understanding depends upon communication of disparate findings and theories which may best explain the data that are available.

There are two ways to interpret the story, however. The first way is to proclaim that there is one all-encompassing theory that unifies all other theories. At first, one might intuitively think that these people would be better off creating a unifying theory to arrive at the truth, rather than exerting the effort and spending the time necessary to trace along the entire elephant. The second way of interpreting the story is to point out that, until these people reach each other's hands, there is no reason to believe in the elephant. In fact, even if they did reach each other's hands and determined that the object was an elephant, they still could not answer the question of what color the elephant is. How could they verify the truth of their conclusion, and what use would these individuals have for that knowledge?

The one thing that both of these interpretations can agree upon is which situation would be worst for arriving at any practical knowledge of the object: What if the three people could not communicate with one another or chose not to? What if each person's description fell on deaf ears? Without the ability to hear the others' descriptions (even if all three conclude that the others are talking about completely different objects), each individual would be confined to their own observations and could only know the other traits through their own exertions.

In short, science—consisting of methodological investigations for prediction and control of the natural environment— is, epistemologically speaking, a social activity. A single individual does not make significant discoveries or establish hypotheses in any meaningful and long-lasting way. To accomplish these actions, the critical assent of the relevant community is needed. Thus, without an appropriate sort of review or referee process, science would be impossible. Nonetheless, there are better and worse systems of review, and I shall maintain that current journal review practices should be reformed.

In publishing, science requires accessibility. By accessibility, I simply mean that theories and data must be retrievable in order to confer any benefit to the scientific community. Removing subjective interpretations, as a result of restricting publication, may limit the power of the objective verification. Most likely, the subjective interpretation that is eliminated will be one of the confirmatory investigations. While the loss of confirmatory investigations is usually not great in individual cases, this result does still weaken the claim of a fact, having one less confirmation. Quite possibly, an improperly conducted investigation is removed from the scientific knowledgebase. Such an occurrence would not be disastrous, as the results were not obtained by the standards and rigor necessary for thorough investigation. Finally, a properly conducted investigation yielding different results might be removed from the verification of a

fact. This outcome is the most concerning, as it means that something is missing from every other account. In this case, a falsifying investigation is missing from the final analysis of a fact.

Such an investigation may also go unnoticed if there is an overly entrenched paradigm, or school of thought and practice, in place. If the individuals investigating a subject have reached consensus, the falsifying investigation may be ignored or discredited, much like the investigations that were improperly conducted. "When confronted with major anomalies, Kuhn's normal scientists simply ignore them. Kuhn argues that 'no part of the aim of normal science is to call forth new sorts of phenomena; indeed those that will not fit in the box are often not seen at all'" (Walker, 2010, p. 435). If Walker is correct, then science progresses according to paradigm shifts. During one paradigm, any alternative explanation is dismissed. The dismissal is not a problem, should the paradigm fully represent the subject matter at hand. However, if the paradigm does not fully encapsulate the subject, properly examining all needed aspects, then a new paradigm will be necessary later on.

We might consider dogmatically holding to a paradigm, in the face of all evidence and reason to the contrary, as a bias. Bias, as understood in this work, constitutes a skewing of the methodology in favor of one perspective or interpretation over available alternatives. Generally, bias may be considered akin to favoritism.

The reduction of bias becomes a main priority of many researchers, along with getting new results, of course. If the literature is biased, then it is possible for a false paradigm to prevail longer than it should. In more than one way, a biased literature and knowledgebase are costly. Time and money are lost on investigations that are fruitless. "Publication bias can lead to the formulation and testing of hypotheses based on false impressions from the scientific literature, wasting research opportunities, time, and money. This violates an implied contract from funders"

(Shields, 2000, p. 771). Shields makes an interesting case for the funding of research. That which does not produce results is ultimately more costly, especially if other experiments are based on this faulty research. However, eliminating research in a biased manner may also be costly if experiments are repeated by new researchers who are unaware that their investigations are actually replicating a previous experiment that has already failed. Some sort of record for failed experiments would prevent mistakes from being repeated, saving money. Experiments that are also ignored under one paradigm may be lauded under another, so keeping a record of them might be particularly useful in the future, saving more money in the long run.

Biases

Human beings have the ability to think extremely frugally, conserving mental resources by developing heuristics that simplify complicated matters. While such an adaptation can have extremely positive benefits, these heuristic processes also come with the risk of being incorrect. "People rely on a limited number of heuristic principles which reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations. In general, these heuristics are quite useful, but sometimes they lead to severe and systematic errors" (Tversky & Kahneman, 1974a, p. 1124). Tversky and Kahneman, founders of the heuristics-and-biases program, thought that these heuristics may often lead to fallacies.

Since the days of the heuristics-and-biases program in the 1970s, however, more optimistic perspectives have risen. One such perspective says, "Finally, whereas the heuristics-and-biases program portrays heuristics as a possible hindrance to sound reasoning, we see fast and frugal heuristics as enabling us to make reasonable decisions and behave adaptively in our environment" (Todd & Gigerenzer, 2000, p. 739). Rather than looking at the costs of heuristics, the Adaptive Behavior and Cognition (ABC) Research Group, Peter Todd, and Gerd Gigerenzer

prefer to examine the ways that these heuristics might prove valuable to human adaptation, conserving cognitive resources in the process.

There has been support for this perspective already, even before the heuristics-and-biases program began lamenting the tendency of heuristics to lead toward fallacious reasoning. Herbert Simon, one of the founders of today's cognitive science, in examining the differences between expert chess players and novices, came to the conclusion that the experts were better equipped due to the heuristics that they had developed. During a review of a book on such a topic, Simon says the following:

> The evidence debunks the idea that the chess master 'thinks faster' than the novice, or that he can 'instantaneously' explore 'innumerable' possibilities. On the contrary, the master's advantage in exploration appears to stem entirely from his superior selective search heuristics, based on knowledge and experience. (Simon, 1966, p. 526)

The ability of the chess master is not to see all of the possible moves and then to select the most preferential outcome, but rather, the chess master limits the range of what is considered to that which is most important for the given situation.

One recent study has confirmed this point, examining the ability of expert chess players to look at important areas on the board. The article says, "… chess players are able to use their memory for chess configurations to guide their search for the best move on the board, rather than exhaustively searching all possible moves" (Sheridan & Reingold, 2014, p. 5). The article maintains the perspective that fast heuristics are more effective for experts than slow considerations of all of the opportunities present.

These sources show that heuristics can be considered in one of two ways, as shown in the elephant example. Either heuristics are adaptive, and more emphasis needs to be placed on their

implementation (we need to trace along the elephant and come up with more explanations as we move along), or heuristics are prone to failure and need to be discouraged (each person's interpretation is lacking and there must be a unifying theory). For skills such as chess, the advantages conferred are apparent; however, scientific investigation may actually be worsened as a result of heuristics. Most likely, both perspectives hold a grain of truth. Heuristics are not going away, unless a technology is devised that can combat the human tendency to oversimplify matters. While a chess master may be better than the average novice, a super computer that could calculate all of the possible outcomes and select the ideal move would be better by far. Unfortunately, the development of such a technology may be unfeasible and the cost of its implementation may have a diminishing return.

Should a researcher seek to reduce bias in the context of scientific publication, there is not only publication bias to be aware of but editorial bias as well. Matías-Guiu and García-Ramos (2011) define publication bias as "situations in which the results have a bearing on the decision as to whether or not to accept a work" (p. 2) and editorial bias as "situations impacting the decision to accept a manuscript and having to do with the authors, either due to their origin or characteristics, or due to their setting" (p.2). Editorial bias is obvious in the case of a ruling paradigm in that the paradigm excludes alternative interpretations. While there are reasons why one paradigm might stand out against all other alternatives, the ruling paradigm's status does not imply its infallibility or that there are not better explanatory paradigms available. The reasons for the success of the ruling paradigm might be purely cultural or conventional, meaning better explanatory paradigms are left out of the limelight as a result of the heuristics employed by researchers under the influence of the current ruling paradigm.

Researchers also often rely on heuristics in determining which lines of research are worth pursuing. It has been experimentally confirmed that "heuristic processing can bias systematic processing when evidence is ambiguous" (Chaiken & Maheswaran, 1994). This finding suggests that if evidence is ambiguous people may resort to using shortcuts in their thinking. Scientists, who are faced with the ambiguous position of determining which subjects are the most important to study, may make their decisions based on heuristic processing, rather than systematically determining the research with the most potential.

Researchers are certainly not exempt from human error. A recent article, (demonstrating that only 36% of the experiments they replicated in psychology had significant results) mentions that "Reproducibility is not well understood because the incentives for individual scientists prioritize novelty over replication" (Open Science Collaboration, 2015, p. 943). The excerpt shows that there are few incentives for scientists to replicate studies. This major bias to the field is likely to go unchecked without a proper adjustment to the incentives in place. Novelty, while incredibly useful in publication for presenting new discoveries, is not the only metric by which the quality of publication is determined, after all.

An Unclear Solution

These biases in publication reveal a clear skew in the scientific knowledgebase, but how to solve the problem is unclear. Open access publishing could be argued to potentially sidestep many of the issues inherent in editorial and publication bias, but there are those who think that open access would damage scientific advancement more than benefit.

Bringing up open access publishing, Osborne says, "Scholarship is markedly improved by referees and editors; the emphasis needs to be put on making available the most accessible scholarship, not on making more scholarship available" (Osborne, 2015, p. 637). This statement

certainly seems to represent the position of many of the traditional journals today. However, the stance does not address the issues posed by paradigm shifts, editorial bias, or publication bias. If journals focus on making scholarship accessible in the way Osborne understands, there will be greater potential for editorial bias.

One possible way of improving the quality of research, proposed by Teixeira da Silva and Dobránszki (2015), is post-publication peer review, "an efficient complement to traditional peer-review that allows for the continuous improvement and strengthening of the quality of science publishing." By reviewing that which has already been published, the scientific community may ensure quality and select the most important findings that the scientific community needs to know. Their recommendation of having post-publication peer review in tandem with traditional peer-review, however, does not seem to be enough to combat the publication and editorial biases that Matías-Guiu and García-Ramos describe. The question must also be raised whether simply improving traditional peer-review would effectively have the same outcome as post-publication peer review.

In light of the recent controversies over academic publishing, such as those concerning Sci-Hub, there are many good stances both in favor and against open access. "The issue was highlighted last month, when all six editors and all 31 editorial-board members resigned from *Lingua*, a prominent linguistics journal, after a disagreement with the journal's publisher, Elsevier, over how much libraries and authors should pay" (Wexler, 2015b, para. 3). Elsevier and other publishers know that publishing is never free of charge. The editors who left Elsevier and started an open access journal have different concerns than funding, however, fighting to allow for the scientific community to have access to pertinent information.

Another contribution to the traditional peer-review and open access debate is the complaint that publishers of journals profit from the research of others but do not take on the financial burden of funding research themselves. "The growth of open access called into question the contribution of commercial editors to scientific publication, bearing in mind that their core activities, preparing texts and reviews[,] are carried out at no cost to the publisher" (Camargo Junior, 2012, para. 20). Much of the cost of research comes from other sources, such as universities, private organizations, or the public. While the researchers are expected to meet the specifications of those who fund their research, as Shields (2000) points out by mentioning the implied contract with funders, researchers need not be subject to the specifications of journals. It is important to keep in mind that the implied contract with funders also has great potential to bias research as well.

The case of publicly funded research may prove difficult. "The findings of research funded by the public should, it is argued, be made freely available to those who have paid for it" (Parker, 2013, para. 3). If researchers are expected to meet the specifications and demands of the public who fund their research, should the public not also have access to the results? Making the results open access might be more ethical, as well as promoting a more informed and active public in the scientific processes. However, opening scholarship to the public may also have a deleterious effect if a full disclosure may inhibit or slow progress. Should all of a researcher's notebooks and data be turned over as well, even before the experiment has concluded? The public could argue that they are entitled to everything they have funded, adding bureaucratic oversight to an already constrained process.

What is certain is that the implementation of open access would not be too costly in terms of time investment from researchers. In a review, Bhat says, "The study by Carr and Harnad

(2005) claims that self-archiving is not time-consuming for scholars. It is about ten minutes per paper, or just over half an hour for a year's research output" (Bhat, 2010, p. 2). This study shows that implementing an open access repository that is compulsory, as some advocates might claim is necessary for the transition, would not actually involve too much more exertion. If the traditional peer-review process is maintained in tandem with an open access repository, then the issues of quality and quantity may both be addressed. The knowledgebase would not be constrained by the current paradigm, and the paradigm would be free to select what it deems to be of most value. In fact, as paradigms shift, articles that were previously ignored under one paradigm may reemerge as exemplars of a future paradigm. These articles only stand a chance of reaching that status if they are not prematurely ousted from publication, though.

Another adage might help to convey the point. In a remote village there is a bush on the side of a trail. This bush is unappealing to look at for the locals, and they can think of no use for it. An illness besets the village and one person, by sheer circumstance, stumbles upon this bush. Thinking of no other way to cure the malady, and acting out of desperation, the person begins to eat the leaves from this bush. Within one day all of her symptoms subside. The villager shares her discovery with the rest of the village, who proceed to use the bush as a medicine. One can easily envision another scenario where the village grows discontent with the sight of the bush and removes it as an unwanted weed. In this case, what might have been their only chance at survival is now destroyed in ignorance.

The bush, like theories that exist outside of the dominant scientific paradigm, is looked at with mild disgust. While the villagers might have found a similar bush after searching far enough, it is much better for them to have not removed the bush at all. Similarly, the scientific knowledgebase is better off not removing theories that do not fit the current paradigm. After all,

there is a possibility that the perspective may be useful later in another paradigm. If the perspective is not published and never enters the scientific knowledgebase, there may be an independent study that later turns up the same results, but this doubles the total cost of researching this one topic.

The next chapter will explore different conceptions within science. The third chapter will examine heuristics as adaptive rules of thumb. The fourth chapter will examine the opposite argument, regarding heuristics as biases to be avoided. Then, in the fifth chapter, arguments against the traditional publication system will be considered, followed by arguments in favor of open access publication in the sixth and last chapter. The last chapter will demonstrate how an open access repository can properly address the concerns of those who wish to have stringent scientific quality assurance, more access to a much broader assortment of articles and perspectives, want to reduce bias in the publishing of scientific knowledge overall, and actually promote further innovation in the sciences.

Monism and Pluralism

Within the scientific community, there is a need for communication. Researchers must effectively and reliably exchange their results with their peers and, in many ways, put their findings to use within the community and applied sectors. However, it is important to note that not all researchers agree on one interpretation of the world or the means by which their understandings ought to be communicated. While one researcher might believe in a monistic conception of the universe, another could just as well discount the theory and espouse a stance in support of pluralism. Likewise, while one researcher might argue for the need of accessing pertinent information related to their particular field through a journal that screens out "bad science," another researcher might have different standards of quality than the journal and seek information that has not been pre-selected and cherry-picked in such a fashion.

This work argues for a centralized and commonly accepted open access repository for all scientific knowledge, publishing before the peer-review process. If the scientific community can agree upon one or a few repositories to store all of its information, then data will be easier to access and great strides can be made in scientific innovation for monists and pluralists alike.

The traditional peer-review system greatly delays scientific advancement (Mesnard, 2009, p. 913), while skewing the epistemology of the scientific community. This skew is, of course, intentional, with the desired goal of enforcing standards of quality. The traditional system of peer-review (where works are scrutinized by other experts before publication) is in place to ensure credibility, avoiding biases and assigning credit where due. This system has the unintended effect of further biasing the knowledgebase, however; some articles are published simply because of who wrote them and their standing with the scientific community, journals

will typically only publish what falls in line with their paradigms, and any new research will be based upon an already skewed epistemology.

Whether or not one takes the view that there is one kind of world or many, researchers can benefit from having access to the full range of literature to date. While the monist supports the view that all of the disciplines in science refer to differences of degree within the same kind of world, pluralists state that the divisions in science are differences of kind. Pluralists maintain that divisions in science share different goals with understandings that do not overlap into one grand, unifying theory (Schaffer, 2016).

A centralized open access repository would almost certainly be used by monists to advance their agenda of unifying disparate theories and fields, while pluralists could benefit in ways that may seem counterintuitive *prima facie*. Monists would have immediate access to some of the most radically different fields imaginable, capable of constructing far more bridges between fields than currently exist. Due to the current system, which depends heavily upon subscriptions, researchers within one discipline of science are islanded to the top journals of their fields. To gain access to many journals is costly, a price that must be either paid for by the individual researcher, the organization of employment, or libraries. With an open access repository shared by all fields, connections could be made more rapidly and communication between fields would become much more commonplace.

On the other hand, pluralists could also benefit from such a system. While pluralists are less interested in bridging fields or looking at information that is seemingly unrelated to the goals of their particular field (as they believe these differences to be ones of kind and not degree), it would prove more beneficial to have access to all of the information. What might not be

important to one field could later prove beneficial as the goals and directions of the field shift to accommodate new demands.

The best way to conceptualize this use of the data would be to envision a ship without a system in place to detect objects underneath the water. The people aboard would only know the existence of an object below-water when such an object has already breached the hull. Rather than waiting for such a titanic failure of foresight, it is better for the people on board to develop a detection system other than sight and sound. Having more information is not a waste of resources if patterns may be detected early. While monitoring often goes unneeded, seeming to needlessly scan and rescan, having radar for iceberg detection would certainly come in handy. Similarly, the heuristics employed by pluralist researchers would benefit with more knowledge should a pattern become visible that spells certain disaster for the heuristic (in other words, should it become maladaptive). Through continuing to search for potential shortcomings in the heuristics they employ, pluralists may successfully navigate the uncertain waters of scientific discovery with more robust heuristics.

Researchers and scientists are necessarily biased, as they rely on fallible human cognition and information collection. Depending on the world concept the researcher has, this bias may be viewed in a positive or negative light. The monistic conception of the world views discrepancies negatively as the perspective is interested in the correlation between our understandings of the world and the way the world actually exists:

> It is not built into the formulation of *Existence monism* that the one concretum has any particular nature. It might be my nose or your left foot. It might be material (realist) or mental (idealist) or neutral. Idealist and neutral forms of existence monism may or may not identify the One with some sort of divinity. Materialist and neutral forms of existence

> monism typically identify the One with the whole cosmos (Horgan and Potrč's 'blobject'). (Schaffer, 2016)

In this tradition, there is only one correct and true understanding of the world. Better science is that which more accurately and reliably aligns with the way the world fundamentally exists, independent of human interpretation.

The pluralistic conception of the world does not share the same assumptions. In fact, it is typically much more practical and centered on applied solutions to human problems. Pluralists do not attempt to find coherence between their understandings and unobservable, "true" conditions of the world. Rather, results determine which theories are considered better and dictate how theories should progress and change. David Danks (2015) describes, "Rather, the position is that there are multiple incompatible ways that we ought to understand our world depending on our goals, and so the pursuit of a unified (scientific) ontology is fundamentally misguided" (p. 3603). Truth for a pluralist is dependent upon the goals setting out and whether the theory lends itself to the desired results. In this way, the cognitive heuristics employed by researchers are less "biases" and more adaptations to environmental conditions.

Heuristics are particularly adaptive for decision making in uncertain situations. When a person lacks proper information because no information on the subject has been collected yet, or the information is unavailable to the decision maker, then the individual may be forced to implement different strategies in determining the best course of action:

> For trial and error (including the proverbial hypothesis and test) is just the exceedingly slow, serial version of the basic evolutionary mechanism of partially blind or undirected variation plus selective retention (Campbell 1974). This mode of inquiry is weak, but we can do no better until more domain knowledge is available. (Nickles, 2009, p. 5)

Unlike subject areas that have plenty of information available, the decision maker is unable to look at all of the variables to assess the best outcome. Rather, the individual must make use of a comparatively crude algorithm.

Such a heuristic would estimate a sufficient decision from only the most pertinent of details. This decision might not be optimized or ideal, but would accomplish what the decision maker set out to accomplish. Incorporating unnecessary details, unrelated to the goals of the decision maker, might skew the conclusion, leading to less effective action.

Two of the best sources for this view of heuristics as adaptive are Peter Todd and Gerd Gigerenzer. Their view is that heuristics have a place in decision making, particularly in situations of scarce information. Otherwise, how else could a viable option be formed? If all of the available information was necessary to determine the path of best outcome, and little to no information was available, then action would necessarily be halted. However, with adaptive heuristics, progress may make strides. When one heuristic proves less effective, it may be traded for a potentially better heuristic.

Heuristics, as best understood, are simple rules-of-thumb for determining action. The rule-of-thumb does not overcomplicate decision making by making reference to every detail, but rather, only the important details sufficient to accomplish one's goal. "It is fast because it does not involve much computation, and it is frugal because it only searches for some of the available information" (Gigerenzer & Todd, 1999, p. 4). In the stock market, there is the common phrase, "Buy low, sell high." This advice is more than just a course of action; the phrase is a calculated decision following a rule that is intended to maximize profits. These four words hardly exhaust all of the related information to uncover the optimal way to make money, but have generally

worked to achieve the desired goals of stockbrokers. In other words, the words serve as a convenient heuristic.

Pluralists would be likely simply to perceive heuristics as adaptive rules-of-thumb, while monists are much more inclined to view heuristics in terms of biases. As a result, pluralists attempt to increase the adaptiveness of theories to meet divergent goals, and monists attempt to reduce the amount of bias in the literature.

The traditional system of peer-review is most closely aligned with that of the monistic perspective, attempting to create consensus within the scientific community and to reduce the amount of bias present in the literature. That is, the traditional system of publication aims to reduce the variance between our understandings of the world and the way the world actually is. This philosophical realism is a tacit assumption of researchers and scientists who attempt to gain better understandings of the world through the scientific discovery of underlying principles and laws of the universe.

Pluralists, who use adaptive heuristics to attain specific goals and not to understand the underlying principles of the universe, are much more aligned with the benefits that a centralized open access repository could offer the scientific community. Since an open access repository does not in and of itself attempt to reduce bias (ironically increasing epistemic bias in the process), far more paradigms are given a chance to thrive.

A system of publication that publishes content before the peer-review process allows for more domain-specific journals to arise, as needed by each particular discipline. Anyone could access the data and the articles that are stored in the repository, meaning that anyone could start a journal with what s/he considers to be top picks that all researchers (of a particular field) need to

see. This development leads to the proliferation of different paradigms, or research programs, that would succeed or fail according to their own merits.

Some paradigms might arise that run contrary to the goals of the current system of publication. For instance, it is possible for there to be a journal that only selects examples of experiments that were improperly conducted from the open access repository. While this journal might seem to completely go against the interests of scientists who attempt to maintain rigorous standards, people learn as much (if not more) from failures as they do from successes. A journal that demonstrated bad methodological approaches could serve to elucidate what researchers should avoid in their own work.

Journals may also be created for results that do not meet statistical significance. Depending on the field that one belongs to, such a journal could seem either completely harebrained or incredibly resourceful. For medical disorders that are relatively unknown and unstudied, treatments without statistical significance might still prove more beneficial than the current best-practices. As a result, the need for a journal compiling results with near-statistical-significance becomes abundantly clear.

Journals that focus exclusively on failed results of experiments would have a much more subtle use in the sciences. These journals may help in pointing out directions of research to avoid, signaling dead-ends of knowledge. A journal that compiled failed results could serve researchers who wished to avoid costly investigations into topics that have already not yielded the expected results. However, a journal of this sort may also be used to show why certain theories are incorrect.

If the failed results belong to the replication of another study, such a finding may demonstrate the unreliability of the first study. The failed results might be used to falsify the

first study. On the other hand, such a finding could also demonstrate that, from the time of the initial study to the replication, the subject matter has changed. A third, unseen variable may be responsible for the change in results. Hence, replications could serve to be useful in demonstrating changes over time. Entire journals may be made simply to show the results of replications, either to falsify or to demonstrate changes over time.

Historical records can prove invaluable to researchers for keeping track of changes over time. With the advent of computer technology, the Internet, and smart phones, more information is available now than ever. In the past, if a tornado only passed by one rural farmhouse, it might have gone unreported. There would be no historical record of such an occurrence, so it would have never happened in the eyes of history. Nowadays, if a tornado only passes by one rural farmhouse, all of the friends and family of the people who live in the house might receive a Facebook notification regarding the incident. In other words, there is a historical record now for a plethora of seemingly trivial facts. Whether or not these facts could prove useful one day, however, remains to be seen (like the example of the bush from the first chapter). What if the tornado occurred in a location that meteorologists previously thought impossible for tornadoes to form?

Independent verification may also be gleaned through historical records and may prove helpful in corroborating theories. An open access repository that does not exclude articles from publication due to any particular dogma concerning upholding standards of research quality would act as a sort of historical record for scientific discovery.

One example of the need for historical records comes from the history of astronomy. In an article determining whether there are indigenous accounts of supernovae, the question of whether the Anasazi independently observed the supernova of SN 1054 is raised. Hamacher

writes, “Some researchers claim that a motif near a hand stencil and a crescent moon represents SN 1054, which was visible in the sky from the site during the period of Anasazi culture and would have appeared below the crescent moon on the date it was first visible, as noted by Chinese historical records” (Hamacher, 2014, p. 6). The author then describes how the public favors the interpretation of the Anasazi representing the supernova of SN 1054, while experts disagree with the interpretation. I like this example because it is ambiguous and unclear as to whether the Anasazi truly independently witnessed and recorded the occurrence.

The independent observation of the Anasazi would serve to corroborate the Chinese historical records; however, there is a disagreement on the facts. This controversy only came about due to the material record of the Anasazi and the historical record of the Chinese. Without these two records, no controversy could exist. Similarly, until more data are brought forward, the question will remain unanswered.

In response, one might pose a separate question: Why would anyone need to know whether the Anasazi independently observed and recorded the supernova of SN 1054? It depends upon one’s goals. For astronomical historians who make their livings off of such a question, the reason is quite clear. Besides, let us imagine that the answer carried a great deal of weight beyond earning one’s daily bread. What if the supernova had major cultural (e.g., astrological) significance?

To make the point closer to home, what if a lack of historical records (or scientific record-keeping) led to a dearth of information on climate change? Let us suppose that due to concerns of frugality, information related to climate was never recorded or kept beyond initial measurements. To keep a record of something so seemingly constant may be seen as wasteful and needless. As a result, climate changes would go unnoticed (possibly as weather) until the

effects were abundantly clear and the point of no return was passed. Thankfully, we are capable of noticing shifts in our climates and we stand a chance of rectifying the situation before our planet is unsalvageable.

Unless data are collected on multiple occasions and replication studies are conducted, it will be impossible to know which theories are still viable and which have expired. In that sense, replication studies act as a sort of historical record for theories and demonstrate the conclusions that may no longer be applicable and the conclusions that may still work.

While there are already private websites on which researchers may publish their results, this option is in no way the optimal way of publishing so that the information is easily accessible for the rest of the scientific community. Yes, the information may be open access, but the expenditures in terms of time and resources to search for relevant information would often outweigh the potential benefits of finding the results. Having one centralized location for this information, or a few well-known and accepted repositories, would help to ensure that the information within the scientific knowledgebase is easily accessible.

Another reason for a centralized open access is the ability to communicate findings to the public. There is not only a divide between different disciplines of science but also between research results and the general public. A large reason for this divide is to ensure that only qualified researchers are contributing to the generation and discussion of scientific knowledge. However, with greater access to primary sources, the public stands the chance of becoming better educated. Credentials also do not guarantee competency. It is entirely possible for the general public to discover patterns in the data that the most qualified of researchers might have missed.

In fact, there have already been initiatives to increase public cooperation in solving research problems. "One of the earliest distributed data analysis projects (dating from 2001) was

Clickworkers which asked the public to count the number of craters on maps of the Martian surface returned by the Mars Orbiter Camera (MOC)… Another project with a game-like interface is FoldIt! which asks the public to help solve protein folding 'puzzles'" (Way, Scargle, Ali, & Srivastava, 2012, p. 232). By opening up some of these projects to the public, the public is more involved in research, researchers can allocate more time to more important concerns, and the arbitrary wall that all-too-often separates scientific practice from the general public falls away.

However, along with an open access repository, there comes the question of funding. Who will pay to keep such a format available for the scientific community and the general public? Such a business would not generate a profit without some kind of subscription model in place. It is possible that crowdfunding could sustain the open access repository, but this system of funding would depend upon inconsistent donations of money. Government funding already permeates much of research, so it is not too much of a stretch to imagine a repository sustained through the use of tax dollars. A tax-funded repository of information would most likely be the best model, as the funding would be consistent and no single company or individual would be held accountable for sustaining a sizeable knowledgebase that scientists from all over the world may rely on for their work. In fact, the repository would ideally be arranged to be funded through an international consensus, as the knowledge contained within has relevant applications internationally and cross-cultural comparisons would be greatly facilitated.

Heuristics as Adaptive

Decision makers are bound by time, cognitive resources, and limited energy to devote to the decision making process. As a result, it is no big surprise that people (researchers included) rely on cognitive shortcuts in order to save time, better compartmentalize, and not expend as much energy on making decisions. However, there has been controversy over whether heuristics improve the decision making process by making things easier or tend toward bias and incorrect conclusions.

This controversy has led to two ways of conceptualizing heuristics:

> Two grand metatheories have been persistent rivals in the history of science in general and in the history of research in judgment and decision making in particular… namely, the correspondence metatheory of judgment and decision making and the coherence metatheory of judgment and decision making. (Hammond, 1996, p. 53)

The correspondence metatheory of judgment and decision making is optimistic about the usage of heuristics, acknowledging the ability of heuristics to simplify decision making and facilitate in fast processing of information. Coherence metatheory, on the other hand, is more interested in whether heuristics bias perspectives away from internally consistent accounts. For instance, Newtonian physics may suffice for solving everyday problems but do not hold up against problems in quantum physics. As a result, Newtonian physics cannot be said to be coherent with an understanding of quantum mechanics and the problems within that domain. The two approaches yield two different, inconsistent accounts of the same problem, so logically, they are not coherent.

For this chapter, the correspondence metatheory of judgment and decision making will be explored. In the next chapter, the coherence metatheory will be given more attention. The

correspondence metatheory is typically more interested in pragmatic concerns and practical accounts. "Correspondence theorists commit themselves, implicitly if not explicitly, to a Darwinian approach… The common research aim among these theorists is to examine the correspondence between a person's judgments and a specific state of the world to which those judgments are supposed to correspond…" (Hammond, 1996, p. 62). Judgments must be fit for the particular environment the person occupies. In this sense, heuristics are naturally selected. Those that are unfit for one environment are not selected, while more fit heuristics will be. This approach is less interested in "making sense" within a larger context and more interested in achieving functional goals within a specific situation.

Gigerenzer and Todd present four different accounts of rationality within their book *Simple Heuristics That Make Us Smart*. The first account of rationality is unbounded rationality. They say, "… many models of rational inference view the mind as if it were a supernatural being possessing demonic powers of reason, boundless knowledge, and all of eternity with which to make decisions. Such visions of rationality often conflict with reality" (Gigerenzer & Todd, 1999, p. 5). Since people do not have forever to make decisions, must make decisions without all of the information available, and can only pay attention to a limited number of items at a time, these models of decision making are argued to be presumptuous.

This point is not to say that one answer does not exist for any given problem. Instead, the contention raises doubt regarding human capacities for understanding. "Even in a game such as chess, where an optimal (best) move does in fact exist at every point, no strategy can calculate that move in a reasonable amount of time (either by human minds or computers), despite the well-defined nature of the possibilities to be searched" (Gigerenzer & Todd, 1999, p. 12). Within the game of chess, one optimal move might exist for every turn. That fact does not mean

that people can reasonably arrive at the correct solution within a sensible amount of time. So, advocates for the use of heuristics would implore chess players to forgo the search for optimal moves.

This approach is not favored by most traditional accounts of rationality, seeming to be even a little irrational. If there is a guaranteed optimal move, why would a scientist settle for less? "Traditional definitions of rationality are concerned with maintaining internal order of beliefs and inferences… But real organisms spend most of their time dealing with the external disorder of their environment, trying to make the decisions that will allow them to survive and reproduce (Tooby & Cosmides, 1998)" (Gigerenzer & Todd, 1999, p. 18). Traditional researchers would continue to search for the optimal algorithm to solve every game of chess and die before ever coming close.

So, even though an optimal algorithm may logically exist, supporters of heuristics for judgment and decision making do not concern themselves with finding the optimal strategy. "Thus, we see rationality as defined by decisions and actions that lead to success in the external world, rather than by internal coherence of knowledge and inferences" (Todd & Gigerenzer, 1999, p. 362). Those who are interested with the correspondence metatheories of decision making would prefer to search for realistic and attainable strategies for winning games of chess.

Upon hearing the impossibility of feasibly uncovering the optimal chess strategy, one might proclaim that at the very least, we should come up with a few strategies that are optimized wherever convenient. "The models in the class we call 'optimization under constraints'… holds that the mind should calculate the benefits and costs of searching for each further piece of information and stop search as soon as the costs outweigh the benefits (e.g., Anderson & Milson, 1989; Sargent, 1993; Stigler, 1961)" (Gigerenzer & Todd, 1999, p. 10). Optimization under

constraints is not the same as unbounded rationality, recognizing that there are some limitations. However, this model strives for perfection within the given parameters.

For researchers, one can see why this approach may be appealing. Sure, researchers may be limited, but they can attempt to overcome those limitations and to look at subjects as exhaustively as possible before arriving at a conclusion. However, in fields where little information is available, such an approach is not viable:

> Strong versions of the precautionary principle (roughly, that we should not proceed with a new technology unless and until all possible future risks and benefits are identified and properly balanced) are really just a reappearance of epistemological foundationism in holding that, if we are sufficiently rigorous, we can identify all possible error in advance and take measures to avoid them. At the frontier, nothing close to that is possible. (Nickles, 2009, p. 20)

If decisions are to be made in relatively new fields and areas with a dearth of information, then optimization is not the solution. Rather, heuristics may be employed to arrive at an educated guess and drive these investigations *without* needing to examine all of the variables. In fact, because there is a shortage of information, by examining all of the information, a skewed understanding is much more probable than with sufficient amounts of information available.

Since an exhaustive approach is not always appropriate, perhaps a strategy that looks at less information should be considered. Herbert Simon developed such a strategy with bounded rationality. "Simon's vision of bounded rationality has two interlocking components: the limitations of the human mind, and the structure of the environments in which the mind operates" (Gigerenzer & Todd, 1999, p. 12). Since the human mind is limited, exhaustive approaches are not best. Rather, rationality must simply be fit for a given environment. Not

every move in chess needs to be considered if grandmasters can accomplish the same feats by looking at less information.

In an experiment examining Simon's approach (known as satisficing) with optimization under constraints, it was found that satisficing is capable of achieving the same success as optimization under constrains while utilizing less information. "To the best of our knowledge, this is the first inference competition between satisficing and 'optimal' algorithms in a real-world environment… The result is… [that] [t]he classical norms may be sufficient, but are not necessary, for good inference in real environments…." (Gigerenzer & Goldstein, 1996, p. 646). The optimal algorithms can accomplish the same results as the satisficing approaches, but require much more information and time to evaluate.

So the case is closed, right? Bounded rationality is obviously the best approach for human beings who are short on time, money, and cognitive abilities. Yes and no. Bounded rationality is preferable to optimization under constraints and unbounded rationality, but Simon's satisficing may still not be frugal enough. Proponents of fast and frugal heuristics would say "some forms of satisficing can still require a large amount of deliberation on the part of the decision maker, for instance to set an appropriate aspiration level in the first place, or to calculate how a current option compares to the aspiration level (Simon, 1956b)" (Gigerenzer & Todd, 1999, p. 14). Since Simon has to set appropriate benchmarks, he still has one area that can be refined. Finding appropriate aspiration levels may be time consuming, so the ideal heuristic would entirely forgo the need to find such a level. Whether or not the heuristic works within a given environment is a sufficient criterion.

Heuristics, as Gigerenzer, Todd, and the ABC Research Group understand them, have a few necessary characteristics. "Fast and frugal heuristics limit their search of objects or

information using easily computable stopping rules, and they make their choices with easily computable decision rules" (Gigerenzer & Todd, 1999, p. 14). The heuristic has a rigid stopping rule so that time is not wasted scrupulously examining unnecessary information for a decision to be made. Similarly, a simple decision rule is needed for making sense of the small amount of information that is examined.

If one wished to develop a new heuristic, only three things would be necessary. "New heuristics can be formed through the combination of simple principles for guiding information search, stopping search, and reaching a decision" (Todd & Gigerenzer, 1999, p. 360). So long as principles guide the search for information, when to stop searching, and how to make a decision with the information gleaned, then a heuristic may be employed. The needs of the decision maker change with each environment, so the principles for guiding search, stopping search, and reaching a decision will be different with varying contexts. The environment ultimately dictates whether one heuristic is more appropriate than another.

For researchers, this environmental selection of heuristics means that one discipline may have to use different principles for search, stop, and decision making than another. The needs of one scientific field are rarely the same as the needs for another. As a result, the needs for one heuristic will be different than the needs within another scientific focus. A lot of the difference may be chalked up to the differing goals of scientific disciplines.

By utilizing heuristics, researchers may be capable of meeting the goals of their disciplines and research focuses while only looking at the information pertinent to their investigations. "A computationally simple strategy that uses only some of the available information can be more robust, making more accurate predictions for new data, than a computationally complex, information-guzzling strategy that overfits" (Gigerenzer & Todd,

1999, p. 20). The problem with looking at too much information is that it might not all match the given problem and could actually harmfully skew the conclusions that researchers comes to.

The reason for the successes of heuristics lies with the way heuristics fit given contexts and how many contexts they may be applied to. "There are two reasons for the surprising performance of fast and frugal heuristics: their exploitation of environmental structure and their robustness (generalizing appropriately to new situations as opposed to overfitting…)" (Todd & Gigerenzer, 1999, p. 360). Heuristics are selected by the environment. If the heuristic is appropriate for a given environment, it will succeed in generating needed output for much less expenditure on the part of the investigator. Wherever possible, it is also better to have one heuristic that can be used in multiple contexts. The fewer the heuristics needed, the easier becomes the job of the investigator.

One example of a heuristic that can be used successfully is the recognition heuristic. In an experiment that tested framing effects, it was found that people asked whether one city is larger than another have an easier time than people who are asked whether the city is smaller. "A framing effect exists across logically equivalent choices, indicating that such choices are often informed by considering individual items rather than by making only pairwise comparisons. In recognition-based choice, such item-specific information is obviously more readily available for the recognized item of the pair" (McCloy, Beaman, Frosch, & Goddard, 2010, p. 1050). Since people have an easier time recognizing names and attributing them to large cities (assuming that the city must be large because they recognize the name), this framing of the question is easier. On the other hand, if the logical equivalent is asked, people tend to have more difficulty ascertaining whether the city is smaller than the other.

The results of this experiment shed light on how people do not think logically. Even though it might be functionally the same question, asking whether one city is smaller than another is not as accessible for people. For the other phrasing, a heuristic may be employed, drastically easing the decision making process and more reliably arriving at the correct solution.

Social environments greatly constrain decision making, increasing the need for the usage of heuristics. "Social environments are characterized by the speed with which they can change and by the need to consider the decisions being made by others" (Todd & Gigerenzer, 1999, p. 361). Needing to factor in the decisions of others can add complexity to what might already be a complex issue. The fast pace of social environments also means that an optimizing strategy is not preferred, since it takes more time to process.

To best understand the differences between decision making in a purely observational environment and a social environment, one need only to look at the history of news publication. What used to be a slow and laborious process of verifying every claim has become a rapid-fire dissemination of dubious assertions. "These particular features of social environments can be exploited by heuristics that make rapid decisions rather than gathering and processing information over a long period during which a fleeter-minded competitor could leap forward and gain an edge" (Todd & Gigerenzer, 1999, p. 361). Today, with the advent of social media and faster communication methods, news companies have to adopt different strategies than they relied on previously. The accuracy of the reporting is less important now than beating out competitors who may arrive at the scene first, so the use of heuristics becomes paramount.

Although news reporting is as old as print publication, the rapid pace of modern reporting has prompted the use of new strategies to keep up. "The upshot is this: The faster things change, the more frontier-like our situation, and the more we need the tools of HA [heuristic appraisal]"

(Nickles, 2009, p. 13). The same is true for the sciences. The faster changes are made within scientific disciplines, the greater the need to employ heuristics becomes.

With the creation of an open access repository, changes will occur with more frequency. The same data may be interpreted and re-interpreted by several different disciplines, each with their own goals. If articles are published before the peer-review processes, then new content could be generated much more quickly and the use of fast and frugal heuristics would become necessary components of an investigator's toolkit.

Rather than skewing and biasing decision making, heuristics may be useful for quickly and accurately arriving at decisions. While the use of heuristics is largely unreflective and unconcerned with logical coherence, giving the impression of a decision maker on auto-pilot, these contentions may be viewed as virtues:

> Thus the "automaticity of being" is far from the negative and maladaptive caricature drawn by humanistically oriented writers (e.g., Bandura, 1986; Langer, 1997; Mischel et al., 1996); rather, these processes are in our service and best interests—and in an intimate, knowing way at that. They are, if anything, "mental butlers" who know our tendencies and preferences so well that they anticipate and take care of them for us, without having to be asked. (Bargh & Chartrand, 1999, p. 476)

Heuristics aid in decision making, rather than detracting from the process. Issues arise when the particular heuristic is not robust enough to fit a given environment. However, it is precisely these issues that have caused researchers to be weary of employing heuristics and to insist upon coherence. The avoidance of bias has become a mainstay of traditional scientific approaches and is, in many ways, one of the reasons for a peer-review process. The next chapter will explore the coherence metatheory of judgment and decision making.

Heuristics as Bias

Although people naturally depend on heuristics, even when they are maladaptive and lead to biased understandings, these limitations may be overcome. One does not have to stick with a heuristic that does not work and can, in fact, use slower reasoning to determine whether the heuristics employed will lead to downfall and ruin.

The reason that people have heuristics in the first place is that they are quite often beneficial and adaptive to certain environments. Because one heuristic does not fit all problems, it is possible for errors in judgment and decision making. For this reason, having a slower rational decision making processes can be advantageous in making up for these shortcomings.

Those who subscribe to the coherence metatheory of judgment and decision making view heuristics as necessary evils that are better replaced with thorough, logical analyses. "Heuristics are precisely those cognitive activities that deceive us (thus 'illusions') and prevent the achievement of coherence, and thus rationality" (Hammond, 1996, p. 60). According to this understanding, rationality is impartial, logical, and nearly mathematical in nature. To depend upon the use of heuristics alone would be ill-advised.

If heuristics are so error-prone and rational decision making is better conducted through slow, logical thinking, then why do so many people fall victim to the use of these shortcuts? One would imagine that experience would teach people to use more coherent thinking over time. However, as Tversky and Kahneman point out, this is not the case:

> What is perhaps surprising is the failure of people to infer from lifelong experience such fundamental statistical rules as regression toward the mean, or the effect of sample size on sampling variability. Although everyone is exposed, in the normal course of life, to numerous examples from which these rules could have been induced, very few people

> discover the principles of sampling and regression on their own. (Tversky & Kahneman, 1974b, p. 50)

The experiments that Tversky and Kahneman ran (examining the heuristics of availability, representativeness, and adjustment from a starting point) showed that coherent, logical, and statistical thinking does not come naturally to people. One cannot reliably arrive at this form of thinking through the use of heuristics (or at least those that they focus on).

The solution that Tversky and Kahneman recommend in "Choices, Values, and Frames" is rephrasing equivalent problems so that they match or remove any elements that might lead to psychological framing:

> The moral of these results is disturbing: Invariance is normatively essential, intuitively compelling, and psychologically unfeasible. Indeed, we conceive of only two ways of guaranteeing invariance. The first is to adopt a procedure that will transform equivalent versions of any problem into the same canonical representation… Another approach that could guarantee invariance is the evaluation of options in terms of their actuarial rather than their psychological consequences. (Kahneman & Tversky, 1984, p. 153)

By taking two logically equivalent prompts and presenting them the same way, people may be able to answer consistently. Changing the prompt to avoid psychological consequences, or framing effects, would also work to ensure that people answer consistently. If logically equivalent problems are phrased differently, however, people naturally arrive at different conclusions for each prompt due to the use of heuristics.

Tversky and Kahneman felt that these differences in responses were irrational, since the problems presented to the participants were logically equivalent. People should pick the best outcome for themselves in both situations, regardless of how the options are phrased; however,

nearly all of the participants were susceptible to this deception due to the use of heuristics. "The failure of invariance is both pervasive and robust. It is as common among sophisticated respondents as among naïve ones, and it is not eliminated even when the same respondents answer both questions within a few minutes. Respondents confronted with their conflicting answers are typically puzzled" (Kahneman & Tversky, 1984, p. 151). Even when people were shown that the problems were logically equivalent, they had difficulty seeing how.

Tversky and Kahneman had found a biasing effect of heuristics that can affect just about anyone. "The reliance on heuristics and the prevalence of biases are not restricted to laymen. Experienced researchers are also prone to the same biases—when they think intuitively" (Tversky & Kahneman, 1974b, p. 50). Such a finding casts doubt upon the entire enterprise of science, since even the most qualified researchers are capable of falling prey to illusions.

As Gigerenzer, Todd, and the ABC Research Group point out, even Tversky and Kahneman could not escape the clutches of the biased use of heuristics. "The tools-to-theories heuristic of scientific discovery (Gigerenzer, 1991a) predicts that the laboratory tools entrenched in the daily routine of cognitive scientists will tend to be adopted as models of mind" (Gigerenzer & Todd, 1999, p. 23). Since Tversky and Kahneman used statistics so frequently, this exposure may have biased what they considered rational thinking. For them, any thinking that fell outside of logical coherence and statistical probability was irrational, skewing their model of the mind.

Tversky and Kahneman were shocked by how scientists and experts could be biased, even though these heuristics are useful for purposes other than coherence:

> These investigators would rather work with theories or models or heuristics known to be defective, so long as they are highly fruitful than with supposedly true theories that

> provide no additional insights or tools for research. As Einstein wrote in his autobiography, "The scientist […] must appear to the systematic epistemologist as an unscrupulous opportunist.[1]" (Nickles, 2009, p. 5)

Scientists are still subject to incentivization and do not conduct research in a vacuum. When a finding is significant and contributes to the field, the scientists who discovered the finding are rewarded in kind. So, scientists are more likely to search for significant and novel results than coherent findings.

Even the most supposedly impartial of scientists expound upon the virtues of their bias. As Nietzsche put it: "In contrast, there is absolutely nothing impersonal about the philosopher; and in particular his morals bear decided and decisive witness to who he is—which means, in what order of rank the innermost drives of his nature stand with respect to each other" (Nietzsche, Horstmann, & Norman, 2002, p. 6). Supporters of impartiality in science are less than impartial regarding this topic and only further show their particular drives and desires.

So it seems that the further one goes to combat bias, the more biases that are inadvertently endorsed. Gigerenzer, Todd, and the ABC Research Group raise a criticism of the conclusions of Tversky and Kahneman, saying, "Given this pessimistic view, it is hard to know where to turn for reasonable decisions" (Gigerenzer & Todd, 1999, p. 27). If people are naturally biased, how can we expect them to think impartially without further entrenching themselves in the use of heuristic judgments?

Defenders of the coherence metatheory of judgment and decision making would retort that even though the use of heuristics comes more naturally to people, slower thought processes are not impossible. Certainly, people are capable of training themselves and practicing to overcome their immediate intuitions. The same researchers who studied inattentional blindness

[1] For the source of Einstein's quote, see Schilpp (1949, p. 684)

with the famous invisible gorilla test[2] wrote a book about how our intentions deceive us. Chabris and Simons say:

> If chess expertise resides exclusively in fast, intuitive pattern recognition, then the grandmasters should have made just as many mistakes when they had five hours as when they had just one hour. But under rapid conditions, the number of mistakes went up by 36 percent, a highly significant increase. In chess, having more time to think enables you to make better-quality moves—whether you are the world champion, a grandmaster, or an amateur—so there must be more to making good decisions in chess than just intuitive pattern recognition. The same is true for most of the important decisions we make in our lives. (Chabris & Simons, 2010, p. 238)

Overall, slower thought processes are less prone to errors in decision making. These slower, reflective decisions are more informed and less likely to encounter unexpected difficulties.

It is important to note, however, that the environment for rapid conditions is very different from the environment for slow conditions in a game of chess. Although more mistakes may be made in a rapid game, the opponent also makes more mistakes. So, it would be advantageous to make quick decisions, even if they are not optimal. What matters is whether the strategy suffices to win a match. So, if a rapid player went against a slow player, and extra time was allowed, why would the rapid player not slow down too? It is a completely different environment demanding the use of different strategies.

What Chabris and Simons are most concerned with is the ability to use slower thought processes to check our intuitions. "The rapid, automatic processes involved in perception,

[2] The Invisible Gorilla test of Simons and Chabris has participants watch a video and count the number of passes one basketball team makes, while ignoring the passes the other team makes. During the video, a person in a gorilla costume passes by the people playing basketball. At the end, participants are asked whether they saw the gorilla. About half of the participants remember seeing the gorilla. See Simons and Chabris (1999).

memory, and causal inference have serious limitations, but these limitations become much more consequential when our higher-level, reflective, more abstract reasoning abilities fail to see that we are going astray and make appropriate corrections" (Chabris & Simons, 2010, p. 230). People can catch themselves before their automatic thought processes lead them into danger, if they sharpen their attention with slower reasoning.

The need to consider more information in making decisions becomes even more imperative in an age where information abounds and social systems grow increasingly more intricate. Chabris and Simons say, "Our mental systems for rapid cognition excel at solving the problems they evolved to solve, but our cultures, societies, and technologies today are much more complex than those of our ancestors. In many cases, intuition is poorly adapted to solving problems in the modern world" (Chabris & Simons, 2010, p. 241). In the last chapter, the complexity of the modern world seemed like a ripe place for heuristics to thrive, as social environments were changing faster than ever. However, in terms of knowledge, there is more recorded now than ever. To not use any of the information available for decision making would be more than wasteful; such carelessness might be disastrous.

Using the information that is more readily available today, we can create simulations through the use of technology that vastly out-compute what a human being is capable of. "Technology can help us, but we must first be willing to acknowledge that automated judgements may sometimes be better than our own judgments—a difficult and controversial step" (Chabris & Simons, 2010, p. 240). What makes this step difficult, beyond human vanity, is the possibility that automated judgements may be incorrect. Even with all of the information we feed into these computations, it could be that the algorithm is incorrect. In this way, though,

dependence upon technology is no different than dependence upon heuristics with uncertain outcomes. At least with technology, there is a chance of better, more robust judgment.

Technology does not have to be incredibly complicated to outperform human beings, either. "Indeed, there are already many mundane examples of technologies that have helped us overcome mental limitations. Writing, for example, helped humans preserve historical information more precisely and in larger quantity than would have been possible through memory and oral tradition" (Chabris & Simons, 2010, p. 239). With record keeping, we have access to information thousands of years later that might have otherwise disappeared after one day. In the same way, an open access repository for science would increase the number of records available and expand the abilities of archival research, should the appropriate software and algorithms be developed.

Chabris and Simons acknowledge that there are times and settings that make heuristics preferable to slow deliberation. "But it seems just as reasonable to think that rapid cognition should be most effective precisely when careful deliberation is impossible (due to stress or time pressure)" (Chabris & Simons, 2010, p. 289). As with the chess game example earlier, if more time is available, a person would be better suited making slower decisions and taking advantage of the information available.

Technology is not the only means at our disposal for combating the biases of heuristics, however. "A complementary approach to replacing human judgment might be to change our environment so that our limitations become irrelevant. In other words… we can redesign our surroundings to avoid the consequences of mistaken intuitions" (Chabris & Simons, 2010, p. 240). This solution appears to be the most sensible and sustainable. Rather than training people to overcome their natural inclinations and intuitions (which would require educating each

sequential generation) or developing technologies that can compute information better than human beings, perhaps the solution lies in restructuring our environments such that these biases are not disastrous.

Solutions that acknowledge and incorporate our natural biases seem to be the best long-term strategies. One potential way of combating the disastrous effects of bias might be offered through social intuitionism. Jonathan Haidt writes:

> By seeking out discourse partners who are respected for their wisdom and open-mindedness, and by talking about the evidence, justifications, and mitigating factors involved in a potential moral violation, people can help trigger a variety of conflicting intuitions in each other. If more conflicting intuitions are triggered, the final judgment is likely to be more nuanced and ultimately more reasonable. (Haidt, 2001, p. 829).

By bringing together *more* biased accounts, better and more accurate understandings are possible. Rather than one person weighing all the different ways to see a topic and selecting the best option, which Chabris and Simons would encourage through the use of slow deliberation, it is possible for biased individuals to reach a more coherent understanding through discussion with other biased individuals.

Dialectical approaches to argumentation can be traced all the way back to Socrates, with people bouncing conflicting ideas off of each other to gain a more comprehensive understanding of issues. Rather than individually training slow deliberation, a preponderance of biases could function the same way. In science, a more open format for publication allows such a preponderance of biases to emerge. Rather than confinement to the biases of traditional journals, new journals, fields, and orientations may emerge through the acceptance of open access publication. Then, as different orientations come into contact with each other, more

comprehensive understandings are possible for the community as a whole, although the individual researchers might have their own particular orientations and biases.

The Traditional Publication System

What Is Science (For)?

There are many interpretations of how the scientific process proceeds. Some models emphasize hypothesis-driven investigation while others emphasize more exploratory approaches. Some models show science as uncovering fundamental universal principles, while others eschew such a concept and claim that principles are artificial and empirical results are the only matter of importance.

What the fruitful products of scientific investigation are is equally contested, but the best description lands on two key elements. "The wider viewpoint sees the primary output of science as its ability to intervene in and understand the natural world" (O'Malley et al., 2009, p. 611). Science ultimately helps people to predict and control the environment around them. If a theory does not lend itself to both better prediction of natural phenomena and control over these phenomena, then the perspective is hardly scientific.

The traditional peer-review process and system of publication is currently more in favor of hypothesis testing, but some have begun to argue that many of the scientific developments in history stem from long exploratory, technological, and methodological investigation:

> … [A]ccounts of scientific activity should involve not only the proposal and testing of hypotheses, but also the exploration of phenomena, the development of technology and techniques, and the generation of questions that can be addressed with inductive, model-building approaches (Glass and Hall, 2008; Kell and Oliver, 2004; Cladin, 2002). (O'Malley, Elliott, Haufe, & Burian, 2009, p. 611)

Instead of a linear process that only confirms or falsifies hypotheses, it is possible to have more exploratory techniques through a parallel process. An open access repository would allow for both linear models and more methodological models to be published.

The insistence on other ways of conducting science and of conceptualizing the world does not imply that alternatives are always better. "We are certainly not advocating that all approaches and methodologies should be seen as equal… We *do* think that no single scientific method applies in all cases, and that it is an open question as to which modes of investigation work best under particular circumstances" (O'Malley et al., 2009, p. 615). Setting out, there is no way to know what technique will yield the best results. Uncovering methodologies that are more effective and testing ways that may prove more promising is half of the aim of science.

Recently, the field of psychology has received flak after a massive attempt to replicate many of the field's studies only returned significant results for 36% of the experiments examined. However, the failure has brought up a much larger concern that there are not nearly enough replications. One failed replication could either be a failure of the experiment or be a failure of the replication itself:

> The lesson here is that a single failed replication tells us almost nothing about which interpretation is correct. Instead, it is the accumulation of evidence—paying close attention to the specific conditions that might be relevant to producing the finding, and being careful not to make any relevant changes—that should shape our confidence (one way or the other) over time. (Earp & Everett, 2015)

In this sense, one replication does not definitively falsify anything. It is through the examination of the results of many replications that conclusions may be drawn. This process is much more

inductive, lacking the definitive but sometimes flawed decision-making prowess of deductive reasoning.

Only in opening the communication between researchers and the general public can the public grow to understand that theories require testing over time. Results that may hold true by one generation may no longer hold for the next generation, as conditions shift. "So there is a public-education aspect to this as well. It's vital that nonscientists understand that science is messy (even when it's working as it should), so that they don't flat-out reject it when some of that mess starts to show" (Earp & Everett, 2015). Scientists may facilitate this endeavor to educate the public through reducing hype wherever possible (not inflating the statistical and clinical significance of findings) and allowing for more public involvement in the process of scientific investigation.

Journals Today

Peer-review has many merits that have benefited scientific progression tremendously since being implemented. "Its anonymity allowed referees to criticize without fear of retaliation. Limited interaction among reviewers prevented one voice from bullying the conversation. It added prestige to studies. And it selected, especially at high-profile journals, studies deserving of notice" (Voosen, 2015). The most important part of the process is the ability to select the best and most deserving of studies. Peer-review allows for the scientific community to access the best of the field with the least effort. In that sense, the process is fairly frugal.

However, with all of the benefits of peer-review, there are a few notable problems with making the system a gatekeeper for scientific publication. The screening of articles to ensure quality skews the type of information that becomes available to the scientific community. Another issue is whether the rejection of "bad science" is truly improving the epistemology.

"One analysis found that there is almost no correlation between a journal's impact factor—a controversial measure of the number of citations a title receives that can end up influencing hiring and firing decisions on individual academics—and the proportion of papers it rejects" (Matthews, 2016). If a journal's rejections do nothing to improve the impact-factor, the very metric used to determine success in the current system, then one would not be misguided in wondering whether the rejections are necessary. Perhaps a system that keeps a record of all of the submissions might be capable of determining a more appropriate measure of success.

Journals have also been known to enforce low word counts and to dissuade many of the practices that do consistently yield citations. "'In an era of online searching, a more complete description can attract more eyeballs, the results of more searches and, ultimately, more attention and acclaim'… [J]ournals do a disservice to scientists and their research by enforcing low word counts for abstracts" (Short science abstracts, 2015). Longer abstracts with more key terms improve the chances that a researcher will be able to find the article during a search.

Traditional publication and peer-review is also exceptionally slow, delaying the progress of scientific discovery. Mesnard says that "the cost of submitting to the best journals is higher both in terms of time spent (a paper may be one or two months with a journal before being scrutinized by the editor) and in terms of shaken morale in the event of rejection… [T]he paper could remain unpublished some years down the line (which could leave it out-of-date)" (Mesnard, 2009, p. 913). Separating the peer-review process from the publication of articles could speed up the system and remove the unnecessary deleterious effects associated with the shaken morale of researchers. To put it simply, the process does not lend itself well to the impersonal consideration of results.

Researchers

For ease in understanding the variables at play in traditional publishing, the two sides will be viewed in isolation. When the perspective of the research is examined, particularly their biasing motivations, the picture of science is not pretty:

> Scientists may assume that results and their implications have to be exaggerated and overstated in order to get published. Our finding that scientific abstracts use more overt positive language is also probably related to the emergence of a positive outcome bias that currently dominates scientific literature. There is much pressure on scientists in academia to publish as many papers as possible to further their careers. As a result, we may be afraid to break the bad news that many studies do not result in statistically significant or clinically meaningful effects. (Vinkers, Tijdink, & Otte, 2015)

The use of more positive words does not mean that better content is being produced. Similarly, the demands for positive outcome and publishing more papers have led to an increase in unfavorable practices. Some researchers play with numbers to gain statistical significance, divide work to get more publications, or generally overinflate the importance of results.

Similarly, there is a problem with attempting to meet the paradigmatic expectations of reviewers:

> The perception that peer review is intellectually conservative is shared by grant applicants (Gillespie, Chubin, and Kurzon 1985; McCullough 1989; National Research Council 2007, 149), grant agency directors (Carter 1979; Kolata 2009), and granting institutions (National Science Foundation 2007a, 2). In response, applicants to the National Institutes of Health (NIH) and the National Science Foundation (NSF) downplay the more transformative aspects of their research proposals (McCullough 1989;

> Travis and Collins 1991) or (some worry) forgo submitting paradigm-challenging ideas altogether (National Science Foundation 2007a, 7). (Lee, 2015, p. 1273)

Because reviewers have their own biases, researchers are encouraged to forgo their personal interpretations of the results to meet the expectations of the reviewers. It needs to be mentioned that what the scientist thinks the reviewers want may be different from what reviewers actually wish to see. So changing the behaviors of reviewers might not be the solution that is necessary. Changing the behaviors of scientists and encouraging the publishing of controversial findings are needed.

Although researchers are attempting to publish more content by dividing their work, slowing down the process of scientific discovery as it takes more time to be reviewed overall, there is still a problem of researchers who find something that they intentionally scrap. "Moreover, despite the 'publish or perish' rule and the many papers that are submitted each year, many scholars publish nothing: they think that their findings are uninteresting or have been discovered before…" (Mesnard, 2009, p. 913). The fact that the public does not understand the significance of replication is bad enough, but for researchers to throw away results because they have already been found is unconscionable. If results are rediscovered, there is more weight to the theory. The results demand publication so that the evidence may stack in favor of the theory. Likewise, negative results can prove just as effective in shaking the scientific community's confidence in a finding. Information that may seem trivial at first glance might prove necessary as the needs of the scientific community shift and new paradigms emerge.

Reviewers

Reviewers are not without their own problems. Reviewers, who have to determine which articles are quality and which do not make the final cut, are just as susceptible to biases as the researchers who write the articles:

> Editors have ceded over more independence to expert reviewers, who in turn can exhibit a host of problems. They show preference to papers showing positive results, or they're biased against authors from backgrounds unlike their own. They may prefer their own paradigms and stifle innovation. According to statistical models, their opinions are little better than chance at correctly evaluating a study for its scientific soundness. (Voosen, 2015)

Reviewers who do not accept results that fall outside of their particular paradigm or dogma might exclude unconsciously as well, making correction of these tendencies more difficult. Since a review is not reliably able to determine a study's scientific soundness, there is nothing to suggest that peer-review is a competent gatekeeper for publication. The content available to the scientific community is hyped up to be sound, but in large part remains unreplicated and unreliable.

Likewise, there is a problem of unequal weighing of criteria. Reviewers, due to these unconscious processes, are liable to be inconsistent with one another:

> Traditionally, peer review 'bias' has been understood as review deviation from the impartial application of peer review criteria (Lee et al. 2013, 4-5). Extending this line of thought, commensuration bias can be conceptualized as review deviation from the impartial weighting of peer review criteria in determinations of a submission's final value. Sources of partiality in commensuration can include review idiosyncrasy (Lamont

> 2009) and social bias—such as subconscious racism—against authors/applicants (Lee and Erosheva 2014). (Lee, 2015, p. 1273)

Prejudices of all kinds, including racial and sexual, can factor into the final decisions of a reviewer. Rather than expecting a reviewer to change unconscious processes, it is much more advantageous to bring in more reviewers. By publishing before peer-review in an open access repository, anyone is capable of reviewing the content and offering their own commentary. Some prejudiced comments may prove unhelpful, but the prejudice in reviewing will not be disastrous like it is in the current system, since the prejudice will not serve as a barrier to publication.

A Clear Solution

Publishing companies have become a contentious topic for many researchers. "Critics now worry that Informa, which is a publicly traded company, will respect the desires of its shareholders more than those of the scholars who supply its product" (Kolowich, 2015). Since publishing companies are companies and driven by profit, not the betterment of the scientific methodology, some researchers have to wonder if such a middleman is necessary.

That being said, the publishing companies are beneficial in one very important regard: consolidation. "The trend towards consolidation is not all bad for academics, says Mr. Esposito. A powerful publisher can get a relatively obscure monograph into more libraries or make it easier to discover online… Then again, the publisher might force the researcher's library to pay for books it does not necessarily want as part of a package deal" (Kolowich, 2015). By consolidating, publishing companies are capable of bringing disparate findings together into one location. This consolidation is necessary for science to progress. The need for one agreed upon open access repository is so that researchers do not have an unnecessary barrier to knowledge

acquisition. If everything is published in one area, results are easier to find in searches and applying different data mining techniques to the database would be much simpler.

The alternative is for publication to remain dispersed in different journals, private websites, and many other locations, such that interdisciplinary communication becomes more and more difficult. Likewise, searching through all of these locations becomes exceedingly more difficult, creating more obstacles for data mining. If a company decides to fund its own research, the results might not be made accessible and might be stored on a private server, in order to preserve company secrets. Likewise, the military might not release information in order to maintain secrecy for national security. At this rate, the only information available to researchers would be studies funded by universities and tax payers. Having one centralized repository would eliminate losing data because it was published privately, would facilitate interdisciplinary examinations and data mining, and would bring diverse paradigms into contact with one another (allowing for the dialectical progression of theories, creating more nuanced conclusions after arguments face greater opposition).

The kind of solution to the problems seen in the traditional publication system will have to be more forceful than the voluntarism seen currently. "What is needed is a 'structural solution'—something that has the power to resolve collective-action problems like the one we're describing. In simplest terms, if everyone is forced to cooperate (by some kind of regulation), then no single individual will be at a disadvantage compared to her peers for doing the right thing" (Earp & Everett, 2015). Earp & Everett said the preceding in regard to replication. If replication is to become a new staple of the scientific community, some sort of regulation will be necessary. Their recommendation of requiring graduate students to replicate a study as part of their program of study is a promising solution to the problem at hand. However, for transitioning

to more open scientific practices, a regulation of the same sort will be necessary, perhaps on a governmental level.

The kind of change that is needed can only be enacted through a change to the culture of scientific practice itself. At the end of her work on commensuration bias, Lee says:

> Future research will need to explore the normative desirability and practical feasibility of these strategies for realigning commensuration practices with the aims of science, with a special sensitivity to questions about how to re-engineer the reward structures and culture of science. (Lee, 2015, p. 1280)

In transitioning to the use of an open access repository, reward structures will have to target the supplying of data and the connecting of disparate findings. These are two practices that will prove essential to advancing scientific discovery.

So what are we to do about human bias? We do not place additional restrictions and criteria; we do not seek coherence; we do not transcend bias; we also do not become content with bias; we grow to understand and learn to work with biases, much like that unbearable colleague. Only through generating more biases and promoting different interpretations will better solutions to the problems of science be stumbled upon. Unless different perspectives are published, most of which will likely be untenable, a better perspective cannot be found as reliably and scientific investigation will stagnate. Through the acceptance of an open access repository as the vehicle for communication within the scientific community, the grip of the overbearing biases seen today in peer-review and publication may be loosened and our scientific knowledge will greatly benefit.

An Open Access Repository

Due to the problems researchers face under the current system of publishing and peer-review, alternatives must be considered. There has already been a push to embrace new forums for communicating results within the scientific community. As journals become more selective, the expectations regarding results become greater. The incentives in place for researchers drive them to seek only specific results (significant, positive, and novel), to divide their work to make more publications, and to submit work to journals that are less domain-specific purely for the chance of entering a high-impact journal and to gain the potential for greater citations of their work. These self-serving actions on the parts of researchers to meet the standards of their fields have led to drastic skews of the knowledgebase itself.

Rather than continuing down this treacherous path, some researchers have begun to investigate new ways of disseminating findings. Landhuis describes one such researcher, saying, "'Scientific communication is undergoing a renaissance,' Nosek says. 'There is lots of innovation with new approaches to doing it better. I don't know which will work, but we can't know for sure without trying them out" (Landhuis, 2015). There is no way to be certain what approach will prove sustainable and what approach will ultimately lead to issues like the ones encountered today. Only by testing hypotheses can conclusions be made.

The kinds of sweeping changes typical for the history of science are not always drastic initially. In fact, sometimes, they can be difficult to notice until long after the change has been made. Thomas Nickles describes how the simple change of a tool or technique can overthrow an existing paradigm:

> The nonlinearity point also follows from the fact that we sometimes find, retrospectively, that what triggered the revolution was a result or shift in practice or instrumentation that,

> at the time, seemed pretty normal rather than revolutionary. In such cases the eventual result of a seemingly ordinary cause is an enormous effect. (Nickles, 2014, p. 66)

If the changing of a tool or practice can result in a change to the science, then science cannot be argued to operate purely at the level of theory, confirmation, and falsification. Rather, methodologies themselves can affect the whole system. If researchers begin changing the means by which they share results and forgo the dangerous practices inculcated under the traditional system of peer-review and publishing, perhaps the sciences themselves will change for the better.

Open Science

Some institutions have started to change their practices, joining the movement to increase the accessibility of scientific results. "Starting this year, any work done [at the Montreal Neurological Institute and Hospital in Canada] will conform to the principles of the 'open science' movement…includ[ing] freely providing all results, data, software, and algorithms; and requiring collaborators from other institutions to also follow the open principles" (Owens, 2016). The set of principles that the Montreal Neurological Institute is following are not set in stone for all advocates of open science, but give a great foundation for what open science generally posits.

One way researchers have attempted to speed the pace of discovery and the dissemination of knowledge is through publishing their results before submitting for peer-review. Kueppers describes this process, saying, "'preprints,' or papers uploaded to open-access websites before undergoing peer review…could speed up scientific discovery and allow for broader feedback than the traditional peer-review process" (Kueppers, 2016). By having greater exposure sooner, the potential for feedback increases and other researchers are immediately brought up-to-date on the latest in the field. For fields where time is essential, such as those that investigate medical treatments for diseases, having results sooner can help the field in making intuitive and

responsive decisions. While the results have not been scrutinized yet, they can still help to inform other researchers of potential areas to investigate.

Along the same lines as using preprints, advocates for postpublication review insist on publishing results immediately and scrutinizing them afterward. However, such a practice may result in articles that escape review. Voosen says, "Still, there's no law that every paper must face peer review…'If postpublication peer review becomes the norm, it won't matter where the paper is published,' Mr. Stell says. 'What will matter is what scientists say about the paper'" (Voosen, 2015). If publication were not dependent upon the types of results researchers obtained, then the current system of incentives would be destroyed. Rather than asking which journal an article got into, one would ask more specific questions regarding the work itself. The name of the journal would not bring prestige but the quality of the research might. Only the best articles would rise above the sea of other entries.

Shifting the incentives of researchers is one of the main aims behind the open science movement. If publication were not dependent upon meeting preset criteria, researchers would have less incentive to produce novel, significant, and positive results. These practices of using small populations, dividing work, and not performing replication studies are effects of the current system in place. Under a more open system, researchers would hopefully be more incentivized to:

> build narratives from collections of published observations. And tools that allow scientists to visualize such networks could provide new metrics for success. Rather than being judged by their number of publications or by the impact factor of the journals in which they publish, researchers could be assessed by 'how good a 'seeder' or 'extender' they are,' says Rajendran… (Landhuis, 2015)

Rajendran, the creator of *Matters*, an open access online journal, makes a great point for what scientists ought to be incentivized to do. If rewards and recognition were given to those researchers who were best able to connect disparate findings or to provide more results for others to examine, then one could expect to see more innovation and discovery.

The current system is far too constrictive regarding what it will publish. Exploratory methods and isolated results do not typically meet the standards of the journals. Regarding Rajendran's journal, which does publish such findings, Kimmelman says (as reported by Landhuis), "The new journal could also improve the reliability of the published literature by 'lowering the activation barrier' for making orphan data accessible to the broader community…" (Landhuis, 2015). Instead of having to lump these stray findings with other research to get published, Rajendran's journal allows people to access stray findings much easier. Different narratives are also possible, which would not occur in the traditional system of publication.

Such an open approach would also allow the public to help create narratives or supply findings. "Rajendran hopes *Matters* can also help level the playing field for researchers in poorer areas, who may lack resources such as antibodies and mouse models, 'but can still make good observations'" (Landhuis, 2015). The disconnect between the public and the scientific community has a lot to do with the traditional systems of publication and peer-review. By allowing anyone to access the data, it is possible for someone who is not part of the scientific community to get acclaim for their work in creating narratives or supply data. Public involvement toward such an end would also likely speed up the process.

Since researchers would not have to break up their findings into multiple papers to boost their publications, and there would already be so many data available, work could begin in interpreting the data and explaining the results.

> Ioannidis agrees that there is currently ‘too much salami-slicing of publications into least publishable units on which scientists can claim authorship on seemingly more and more papers’… The journal may help the scientific community move ‘in the opposite direction, one of coalescence rather than fragmentation,’ Ioannidis says. (Landhuis, 2015)

It is odd that the traditional peer-review process attempts to maintain rigor and scientific standards but causes so many counter-scientific practices to emerge. A system of publication before the peer-review process would encourage just the opposite trend, where researchers must now consolidate information.

This behavior makes sense when one looks at the heuristics employed for each environment. In an environment of more scarce information, it is easier and more beneficial for the individual researcher to divide information and boost publication count. In an environment oversaturated with available data, tactics for consolidating information become more needed. As a result, the environments dictate whether researchers overcomplicate findings or simplify their work for ease of comprehension.

Feyerabend long ago made an interesting case for scientific practices that almost exactly mirror the goals and strategies of the open science movement:

> An account of the alternatives replaced, of the process of replacement, of the arguments used in its course, of the strength of the old views and the weaknesses of the new, not a ‘systematic account’ but a *historical account of each stage of knowledge*, can alleviate these drawbacks and increase the rationality of one’s theoretical commitments. (Feyerabend, 1993, p. 31)

Because an open access repository would publish before peer-review (and even after), there would be a record. Open access journals like *Matters* would also have a history of the narratives

proposed to explain the data, criticisms and supports of these narratives, and old narratives could easily be challenged with proposed replacements. Likewise, replications could easily be conducted and used to build confidence in certain narratives.

Historical changes in the data could easily be observed through archival research as well, however, certain techniques may be necessary in order to work with data on this scale. In the same way that consolidating data requires the use of certain heuristics, computer programs would need to employ algorithms for different searches.

Data Analysis

With each datum comes an added cost associated with search. For this reason, heuristics would prove invaluable for any researcher attempting to sift through these mountains of observations:

> "[I]t is far easier to collect the data than to extract useful information from it. Sophisticated techniques… are increasingly being applied to the analysis of these datasets in commercial and scientific domains. As the problems become larger and more complex, researchers are turning to heuristic techniques to complement existing approaches. (Cantú-Paz & Kamath, 2002, p. 48)

The large amounts of data that open science would generate requires the use of heuristics to filter these results and guide one's search toward answers to specific questions. Criteria and possibly even the search mechanism would change, depending on the question.

Different searches require the use of different heuristics. Rather than artificially limiting the scope of the scientific community through criteria applied at the peer-review level, searches could be employed after publication in a way that did not affect the search results of others, targeting the specific criteria related to one's purpose. Since one discipline (and even one

researcher) might have different goals from another, the associated criteria would be different for their searches. The largest possible mistake would be to assume that the same criteria apply sufficiently for all searches. The criteria for one search are not sufficient for every other search, demanding different search results through the use of relevant criteria.

One of the possible heuristics that could be used for archival research of an open access repository is based on evolutionary patterns:

> Evolutionary algorithms create new individuals using simple randomized operators that are similar to sexual recombination and mutation in natural organisms. The new solutions are evaluated, and the cycle of selection and creation of new individuals is repeated until a satisfactory solution is found or a predetermined time limit has elapsed. (Cantú-Paz & Kamath, 2002, p. 51)

Variable solutions are created and matched against an aspiration level. The first solution that suffices is selected.

Another heuristic for data mining is modeled on the way that an ant colony works. "An Ant Colony system involves simple agents (ants) that cooperate with one another to achieve an emergent, unified behavior for the system as a whole, producing a robust system capable of finding high-quality solutions for problems with a large search space" (Parpinelli, Lopes, & Freitas, 2002 , p. 192). This system would probably be best for scouring an open access repository, since the search space would be enormous without the filter that peer-review provides for traditional publishing. If peer-review occurs after publication, then there would be much more information to sift through.

One heuristic is based on the immune system. Because the immune system is capable of remembering pathogens, "it was suggested that the immune network possesses some kind of

learning and cognitive abilities. This leads many people to speculate that the immune system is an excellent learning system and that there are many… application to computer science" (Timmis & Knight, 2002, p. 217). The immune system heuristic would be capable of learning and distinguishing, making the heuristic more robust.

Finally, archival research would benefit greatly from open source programs. For example, "Google announced it would turn its machine-learning software, called TensorFlow, into open-source code, so anyone can use it. 'We hope this will let the machine-learning community—everyone from academic researchers, to engineers, to hobbyists—exchange ideas much more quickly, through working code rather than just research papers'…" (Wexler, 2015a). Open source would allow for anyone with a better program to implement needed changes to existing formats. Fine tuning could occur much more rapidly, in the same way open science would speed along discovery and innovation.

Funding Open Access

In order for open access to be viable as a solution to the dominant biases and skewing tendencies of the traditional system of publication, open access must be sustainable and funded. "His argument, one echoed by academics around the world, is that the public has traditionally paid twice for research: once to fund the research and then again to read the results. But for-profit publishing companies like Elsevier have argued that someone has to pay for the cost of the publication…" (Bohannon, 2015). Traditional publishing has covered the costs through subscriptions. Open access would reduce the ability for these companies to sustain a profit from subscriptions, since anyone could access the material for free. However, that free service is not free for the ones hosting the content.

The issue of funding must be addressed. The interests of the publishers are to ensure quality content and to produce profit, while open science advocates demand the availability of content for the ones who need the information most—researchers. These interests are clashing, resulting in outcomes that no one can predict. Friedrich Engels, in a letter to J. Bloch, describes such a dialectical struggle, saying:

> there are innumerable intersecting forces, an infinite series of parallelograms of forces which give rise to one resultant — the historical event. This may again itself be viewed as the product of a power which works as a whole *unconsciously* and without volition. For what each individual wills is obstructed by everyone else, and what emerges is something that no one willed. (Engels, 1890)

This quote properly depicts many of the challenges scientists will face as they answer the question of funding moving forward. What will result will likely be different than what either group imagined. To get a good idea of what the solution might look like, though, one needs to examine the contending interests at play. The quote also highlights the unconscious nature of these transitions. Natural selection (even on a cultural level) does not choose between alternatives to achieve a specific purpose. Rather, the best solution going forward will be the one that best fits the conditions at hand.

One such result is to charge authors who would like to make their content more available. "And in many other cases [publishers are] offering hybrid models that let authors pay for open access. An increasingly common version of author-paid open access is the 'megajournal,' copying the PLOS ONE innovation of publishing a large volume of papers online across various disciplines" (Basken, 2016). As can be seen from this solution, neither party fully gets what they wanted. The publisher loses money by making content more open, but can offset some of the

cost through author payments. Likewise, the authors may make their works more accessible but are now fully responsible for covering the cost themselves.

Such an option is not preferable, as the burden is unfairly put on the authors that acknowledge the need for open communication of results. Why should they individually sacrifice for everyone else's benefit? A better option is modelled by the Open Library of the Humanities. "The Open Library of the Humanities… [is] funded through a three-year, $741, 000 grant from the Andrew W. Mellon Foundation, as well as by fees from libraries in its consortium. Access is free to all… As more institutions join, the fees get smaller" (Wexler, 2015b). The model presented here shows how a commonly accepted open access repository could be funded through grants, donations, as well as through library and university consortiums. The model has the right idea of spreading costs across many providers. If the public and private sectors could profit from using the information in such a repository, why should the repository not be provided as a public service, available at public libraries?

The United States is not quick to provide public services. Rather, the model that is preferred typically involves charitable donations. "In the domain of funding, scientists are increasingly turning to alternative sources of support, including crowd-sourcing sites (e.g., Experiment.com) and philanthropic and innovation prizes (Knowledge Ecology International 2008; McKinsey & Company 2009)" (Lee, 2015, p. 1279). These crowd-sourcing sites could serve to sustain not only an open access repository but also research projects for researchers or departments that lack the necessary funds. If poorer researchers do not have the means but an excellent methodology, crowd-sourcing might be a viable method for covering their costs.

So if open access journals are already available and costs can be covered through tax dollars, institutional consortiums, private donations, or many of the above, why have they not

caught on? Kueppers says that "for young scientists it's about fear. 'Fear that they won't get that tenure, they won't get that job, they won't get that promotion, or they'll get scooped, and their findings will be less publishable, and it won't get into as high of a journal,' Ms. Avasthi said" (Kueppers, 2016). These fears are legitimate, as the institutions funding research look at the number of publications, the number of citations, and what journals scientists have published content in. Putting one's work online for all to see could be a good way for someone else to steal the idea and get it published in a high-impact journal.

Assuaging Concerns

These concerns have caused researchers to question who would be capable of publishing in open access journals or storing their information in an open access repository, since researchers need to build publication counts to advance professionally. "Does posting preprints make sense for rank-and-file scientists and young researchers… or is it really only an option for researchers who have already made a name for themselves?" (Kueppers, 2016) Researchers who have already been successful do not have the same risks, as the community already acknowledges what they produce by name alone. The system as it is currently organized allows for these positions of prestige to emerge, where a researcher can publish in alternative journals without sustaining damage to reputation or career. In fact, these are precisely the researchers who are able to enact change through setting an example and helping to create a culture of openness in science.

One further concern, not on the individual level, is whether the openness of science itself could be harmful. Research is responsible for many of the boons our society sees, but also many of the tools used for destruction. Military research can have tremendously positive results for the public, as we have seen with the internet. But it is also military research that has devised some

of the most devastating weapons ever used. It is my contention that information, while it can be used dangerously, is still more beneficial for the great majority than a lack of information. A large enough textbook can be used to learn something new or to take a human life. I think in the vast majority of cases, the textbook will either be used to acquire knowledge or will be left entirely ignored on a bookshelf.

National defense should not be the concern of researchers but those who are hired for such a purpose. A much more pressing matter is the possibility of a solar flare interfering with Earth's magnetic field. Should such an event occur, it is possible that the damage could be catastrophic. "In a 2013 estimate, focusing solely on the United States, Lloyds put the price of the resulting damage as high as $2.6 trillion.[3] Today, it's undoubtedly higher still… [S]olar storm researchers are desperately pushing governments to make contingency plans" (Geere, 2016). The risks associated with storing all scientific information in one electronic location are a compelling reason to back up scientific literature with print copies. In order to avoid a Library-of-Alexandria-type disaster, researchers must not put all of their eggs into one basket. That being said, a centralized repository may be backed up on many different servers and on many different media. The essential consideration is for each copy to be a faithful replication of the repository. Then, if one server is tampered with, none of the other servers will be affected. If all electronic copies are affected by a solar flare, there will still be print copies.

Along with the concern of consolidating without faithfully replicating, international agreement may be difficult. Some countries may be more accepting of open science while others may only allow for parts of the repository to be accessible. Again, I do not think that international agreement is a concern of researchers. The responsibility of researchers is to generate and disseminate knowledge, not to kowtow to extra-scientific considerations. Ivan

[3] See Lloyd's of London (2013).

Petrovich Pavlov, the Russian physiologist, is an exemplar of this point: “To a collaborator, who explained his 10-minute delay as a result of the shooting, Pavlov exclaimed, ‘What difference does a revolution make when you have experiments to do in the laboratory!’” (Gantt, 2016).

Apply Pressure

A better method than simply having highly successful researchers lead by example is to have institutions develop policies that will begin paving the way, particularly if they insist on collaborators to do the same. “The insistence that any organization or institute that collaborates with [the Montreal Neurological Institute] will also have to follow open-science principles for that project could help to spread the approach, says Dan Gezelter…” (Owens, 2016). By insisting that other institutions develop more open policies for collaborative projects, then other institutions and the researchers in these institutions will be forced to at least consider the option.

Recently, fourteen universities in the Netherlands challenged Elsevier to make their content open. “Unlike larger countries such as the United States, all 14 universities in the Netherlands have a single bundled deal to access Elsevier’s subscription journals. Elsevier was forced to make a compromise because ‘we stood united,’ Meijer says.” (Bohannon, 2015). The ultimate compromise of 30%, again, is not what either camp wanted, but it is a start in the right direction. However, the entire debacle can be avoided by transitioning to an agreed upon open access repository. If researchers made the transition in a united fashion, then no negotiation with publishing companies to change their practices will be necessary. The need for publishing companies will entirely disappear and the need for competent data miners would just begin.

If we wish to understand why changes toward open science have not been made (even though the means are available and no negotiating is required), we must consider the way that environmental selection works. B. F. Skinner says:

> Why do people continue to do things in the same way for many years, and why do groups of people continue to observe old practices for centuries? The answers are presumably the same: Either new variations (new forms of behavior or new practices) have not appeared or those which have appeared have not been selected by the prevailing contingencies (of reinforcement or of the survival of the group). (Skinner, 1981, p. 14)

Certainly, the publishing companies and peer-review systems have applied conservative pressures, but there are other alternatives available now. Does the fact that these alternatives exist mean that the prevailing contingencies have not selected open science? If researchers wish to change science to be more open for the conferrable benefits in terms of speed, transparency, and reduction of publication bias, then researchers either need to change the contingencies governing their behavior or produce more alternatives.

The same may be said for the theoretical frameworks that researchers choose. Prevailing theories exist because there are either no new theories emerging or the new theories have not been selected under the prevailing contingencies. "The consistency condition which demands that new hypotheses agree with accepted theories is unreasonable because it preserves the older theory, and not the better theory. Hypotheses contradicting well-confirmed theories give us evidence that cannot be obtained in any other way. Proliferation of theories is beneficial for science, while uniformity impairs its critical power. Uniformity also endangers the free development of the individual" (Feyerabend, 1993, p. 24). Not all theories and not all journal articles have to be accepted by the scientific community as a whole. In fact, it is better to have diversity and less agreement in what is allowed to be published. Instead, works should be published then selected based on their merits.

By choosing one open access repository, the ability to search through data using heuristics will greatly increase and by allowing open access, different disciplines may look at the works of other disciplines, greatly increasing theoretical convergence while supporting theoretical divergence. Open access would also allow for more public involvement and understanding of the process. Replications could easily be published, allowing for researchers to track the efficacy of theories over time. Peer-review, if it is applied after the publication process, would likely become more domain-specific. Anyone would be able to use the existing repository and select their top picks. In this way, science may also proceed in a parallel way, rather than linearly. Since peer-review is typically freely done, under the assumption that this work is part of having a research position, nothing would change in terms of incentives. The need to select the best work and make it easily accessible for other researchers will not disappear, and in fact, jobs entirely devoted to creating algorithms to search the repository would likely increase.

Researchers are just as prone to bias as any other person. There is nothing about the traditional system of publication and peer-review that removes bias or increases coherence with any fundamental truth and certainty. William James says, "Biologically considered, our minds are as ready to grind out falsehood as veracity, and he who says 'Better go without belief forever than believe a lie!' merely shows his own preponderant private horror of becoming a dupe. He may be critical of many of his desires and fears, but this fear he slavishly obeys" (James, 1896, p. 236). The current system, which attempts to mitigate bias in scientific literature, has actually only further entrenched one bias in the process. Rather than prescribing an appropriate way to conduct science, researchers should be more concerned with the results of their methodological investigations. Coherence is not a bad goal to have, but it should not interfere with others who might not share the same goal.

Unless there is variability in theories and scientific practices, then better methods will never be uncovered. As a result, we are impelled to publish everything and read only what relates to our goals, rather than limiting ourselves to tried and true scientific practices. James also says:

> For purposes of discovery such indifference is to be less highly recommended, and science would be far less advanced than she is if the passionate desires of individuals to get their own faiths confirmed had been kept out of the game. (James, 1896, p. 237)

Biased researchers, orientations, and practices generate new variations. We should not rule these variations out *a priori* but *a posteriori*. If a variation is not received by the scientific community, then that is its fate. There is nothing to stop the community from returning to it later, however, with the use of an open access repository.

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