Seven Fallacies of Thought and Reason: Common Errors in Reasoning and Argument from Pseudoscience

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Overview:

Humans have a great capacity to be wrong. Our natural biases, habits of thought, intuitions, and heuristics usually serve us well. However, under certain circumstances they can also lead us directly towards error. Intelligent people are more than capable of holding irrational ideas that recruit subjective belief more than objective facts and evidence. Having qualifications and intelligence are no guarantee that ones views are correct. This paper discusses seven common and persuasive errors of thinking and reason. Some are errors of logic; others are more general errors of thinking and reason. These errors are typically directed against science, by modern popular science writers, pseudoscientists, and amateur enthusiasts. One thing unites all these errors of reasoning. That is, they all reflect common misunderstandings of what science is, what it does, and how it goes about doing what it does. Therefore, these errors of reason are united by a complete failure to characterise science correctly. The level of interest in popular science and pseudoscience is increasing, and so is the corrosive misperception of science. There is a real danger that the public's and student's perceptions of science may be influenced by the apparently more visible, vocal and somewhat more intuitively appealing message of pseudoscience. This document outlines just some of the main fallacies, errors, and mistakes of reason commonly directed towards science (with the explicit intention to undermine it). Science is not perfect; and it has never claimed to be infallible. However, science is far closer to providing helpful understanding than any alternative system of knowledge (i.e., belief-systems & pseudoscience). There may be many valid reasons to question scientific knowledge, but the fallacies outlined in the present paper are not them.

There is more than one way to be right, and there are certainly many ways in which one can be wrong. Natural human thinking about the world and the events within it has a particular affinity to erroneous reasoning. Whether it is in the form of a formal logical fallacy, or a more informal mistake of reason, the end point is the same - error. Not all mistakes of reason are costly, but some clearly are. Committing suicide so your spirit can join a supposed spiritual leader flying in a space craft, is perhaps not the most elegant, well-reasoned or persuasive argument. But for some it was (the Heaven's gate cult; see Carroll, 2004). Why? To most of us this would appear to be a totally irrational view, and indeed it is. However giving it the label of 'irrational' does not, in and of itself, explain anything (even though it is accurate). In this modern age of science, how and why do people hold weird ideas? Why do people avoid perfectly adequate explanations and understandings in favour of mystery and delusion? How and why does utter nonsense seem so logical to some people? Why is science not as popular in the conscience of the general public as pseudoscience appears to be?

Despite being in an age that has witnessed an explosion of scientific understanding, changing our knowledge landscape better than ever before, we also seem to live in an age that propagates and celebrates ignorance (Gardner, 1957; Shermer, 2002). It might be an exaggeration to claim we are entering a new dark-age of the public's awareness of science,

but an increasing attraction to anti-science seems, historically at least, all too familiar. At a time when we can send a man to the moon, there are people who think UFOs are flown by aliens who go around abducting and experimenting on humans. At a time when Darwin's theory of Evolution via natural selection has been considerably expanded and supported, some still think that living organisms and the universe were designed by a somewhat more supernatural process. Despite advances from the world pf physics in theories of Relativity, Quantum Mechanics, the evolution of the cosmos, others argue that the earth and the universe is only around 6000 years old. As medicine has helped to rid the modern world of many aliments, there are those who think drinking a homeopathic remedy (water) will cure illness. Still further are those who consult psychics and astrologers before making decisions, who think that the dead live on in the afterlife, who think that unicorns and angels are real, that twins have psychic powers, and that fairies live at the bottom of the garden. Progress indeed!

In more recent times, people holding such questionable views have made an interesting switch from trying to provide evidence to silence the skeptical scientists (partly due to the fact they failed to produce any evidence), to attacking the process of science itself. Because science makes the seemingly (to these individuals) unhelpful request for evidence, it has placed itself right in the firing line from those that seek to undermine it and the knowledge it generates. This process has led to an unhelpful situation where the reality of science and the public's perception of it often differ markedly. Pseudoscience is more palatable to the public as it often provides the message the public want to hear and claims they want to be true (i.e., we all survive bodily death). This gives pseudoscience considerable currency in forming the public's perception of the nature of things in science. However, science tackles how things are, not how we want them to be. Whatever the explanation for why people hold irrational views, one thing is for sure – certain factions of the population seek to undermine scientific knowledge, and promote their 'alternative' system of knowledge and information. However, a closer examination reveals that these alternatives amount to little more than circular belief-systems and unfounded pseudoscience, having little to do with evidence and reason.

Jumping to conclusions often involves a leap towards error.

It is often the case that a particular interpretation or view may well seem so blindingly obvious to the individual it would appear odd to question it. However, this alone does not make such an interpretation necessarily correct or true. In other words, the strength of the conviction that one is correct is no reliable measure, on its own, that one actually is correct (see below). Conviction does not equal correctness! Nevertheless, the level of conviction alone will dictate that the particular view will be resistant to change, and will be held in contrast to the available evidence. This is unfortunate. A useful thing to keep in mind is that whenever an account or idea seems too obvious as for it to be odd to doubt it, it is often useful to do just that.

Our brains are naturally biased to engage with and process information in a particular manner. This is a good thing as it means perception and experience is relatively fast and effortless. There are advantages to survival from these biases as they try to provide instant interpretations of the world and thus free up important resources for other things and new information, which might be threatening. However, such biases also have downsides. As certain things almost always appear a certain way to us (because of inherent brain biases underlying information processing) this can lead us to conclusions and views that are very established quickly, are persuasive, but are in fact quite false. These predispositions are known as, cognitive biases, habits of thought, or heuristics (mental rules of thumb). These biases, which seem perfectly reasonable at first glance, steer our natural and spontaneous thinking in a way that can betray reality and truth.

For example, imagine a man and women are in an elevator having an argument. You enter the elevator to help get to your intended level within the building. During their argument you overhear them mention; 'the house' and 'the children' etc. It would be perfectly natural from overhearing such statements to arrive at the conclusion that the people having the argument are husband and wife. However, the evidence does not directly support this and although such a conclusion may well appear natural and persuasive, these factors on their own do not make such conclusions correct. The couple could simply have been colleagues debating a newspaper story of a family, or even a family situation from a reality television programme. Human reasoning often tries to fill in the blanks – and often does so by generating spurious conclusions to fit the incoming information. Sometimes the conclusion is correct, sometimes it is not. Due to the considerable scope for error in human reasoning scientists and philosophers have developed methods for reasoning about the world.

Enter the role of critical thinking and scientific reasoning. These are strategic mental tools to protect the individual from delusion and error. The tools of critical thinking and the scientific method are specifically designed to navigate around these limitations and natural biases. They fight against the initial reaction we all have that seem to want us to 'jump to an immediate conclusion' which may actually lead us to arrive at a conclusion or opinion that is false. Critical thinking constantly prompts us to ask ourselves, *"to what extent might I be deluded about this issue"*. Science allows us to address this question and hopefully reduce the probability that our views and theories are based in error and delusion.

In the name of science

A great deal of nonsense is touted in the name of science. Many forms of knowledge claim to be scientific or claim to be based on scientific principles – yet nothing could be further from the truth. This is the realm of pseudoscience, a realm riddled with belief-based reasoning and bastardised concepts of science. Pseudosciences are a collection of nebulous ideas, practices, and claims which are packaged as being scientific when in fact they are not scientific at all[1]. Typically a pseudoscience is based on little if any empirical evidence, starts from unfounded premises, violates logic and reason and flies in the face of high-quality evidence which supports an alternative account. On occasion a pseudoscience may begin with a legitimate assumption, though from this sound basis, make spurious unfounded claims. The results are the same – delusion and error. The normal rules of science do not apply to the pseudoscientist; indeed they could not as they are likely to totally undermine it (as they do)[2]. Pseudosciences never produce new insightful knowledge, they are circular and static. Any *research* that is carried out serves only to establish the pre-existing beliefs or agendas of the individuals (committing the *confirmation-bias fallacy*). Here, only certain forms of information count as knowledge.

The worrying thing about pseudoscience is that it presents itself as scientific in nature – yet at the same time as a viable alternative to mainstream science. So the problem here is not only the false interpretations they promote, but the claims that these interpretations are factual in a scientific sense. It is this latter inherent claim of scientific credibility and authority which makes the toxic effect of pseudo-thinking so potent. To the uncritical and ill-informed, a pseudoscientific claim could appear perfectly reasonable. Pseudoscience

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[1] It is important to note that a body of knowledge is not a pseudoscience unless it claims to be providing a scientific truth. Therefore, there is little if any friction between science and many areas of religion because many religions do not claim to rival science in this way (with creationism being one such exception).

[2] Pseudoscience often claims that the principles of science do not apply to it. This is based in the idea that what is being studied is 'so special' that science is insufficient to address it. This is really a case of the *special pleading* fallacy recruited to explain the lack of evidence. Rather predictably, there are no logical grounds provided to support this case of special pleading and so the argument remains unsupported and unsound.

impersonates legitimate science in an attempt to look legitimate itself. Good examples of pseudoscience include areas like, (i) Astrology, (ii) Homeopathy, (iii) Alternative health, (iv), Dowsing, (v) Numerology, (vi) Reflexology, and (vii) some quarters of Parapsychology. In addition, pseudoscientific thinking can permeate many aspects of knowledge including, politics, media, and health. The general public do express concerns that electromagnetic fields from mobile phones may be involved in causing some cancers or that Homeopathy should receive government funding as a viable health treatment programme. At the time of writing there is no definitive published scientific evidence to establish any of these claims – despite what the media and pressure groups may want you to believe.

There is an odd and interesting tension within pseudoscientific thinking. Where pseudoscience has clashed with mainstream science, it has sought to undermine it via many of the fallacies related in this paper. It seems odd that a self-claimed system of knowledge should go to so much trouble to appear scientific, to then undermine that very thing it is trying to mimic. This is a somewhat curious position. Of course, such tensions are subtle and are rarely picked up on in the feverish debate between science and pseudoscience. Pseudoscientists are aware that there is considerable currency in appearing to be a legitimate source of information. They are equally aware that the public's knowledge of science is very limited. Although pseudoscientific knowledge comes from a variety of sources, making a variety of claims, they can all be characterised as containing many central and similar properties. Some of these are discussed in a later section.

Characterising science appropriately

Pseudoscience and the popular media propagate many incorrect and misleading stereotypes about scientists and the process of science. This provides crucial leverage for the pseudoscientist to instil a perverse and twisted notion of science in the public's conscience. This in turn, creates an illusory conceptual space for the knowledge system of the pseudoscientist to exist as a viable alternative to science. Before the contents of any scientific theory can be considered fairly, it is crucial to attempt at least a rudimentary understanding of the process involved in revealing provisional scientific truths. These processes are referred to as – the scientific method.

The scientific method is a collection of techniques and principles that lead hopefully to the uncovering of provisional truths and understanding. The ultimate aims are to arrive at well reasoned, considered, and justifiable conclusions which inform our understanding of the object being studied. In contrast to the popular perception of science being sterile and rigid, science is a complex symphony of methods, techniques, tools, thoughts, ideas and theories. The emerging knowledge is never fixed, but in a constant state of flux. Science is a probabilistic process, not a deterministic one – it does not claim to be 100% accurate and has never claimed to provide definitive proof. Indeed, science explicitly acknowledges that such an achievement would be impossible. Science identifies and examines what are the most plausible and most probable accounts. Shermer (2002) defines succinctly science as;

"a set of methods designed to decide and interpret observed or inferred phenomena, past or present, and aimed at building a testable body of knowledge open to rejection or confirmation" (Shermer, 2002; pp18).

Unlike pseudoscience, the scientific method aims to be objective and impartial, establishing facts in a manner removed from bias and belief. It has no direct and inherently biased bearing on the nature, form or content of any observation or theory. Science seeks to reveal facts about the world without presupposing what they are or how they are ordered. It aims to provide a reliable and valid measure of the object of study. It seeks to develop and uncover new knowledge and understanding rather than merely support or confirm pre-existing unsupported belief. Crucially, science bases its conclusions on a process of external

validation made explicit, endorsed, and shared by the community. It is important to note that any scientific theory can be shown to be wrong – if such evidence were available to falsify it.

Ideas that have come through this process of scientific inquiry are more likely to be based on sound foundations relative to other ideas that have emerged through less rational and veridical processes (i.e., belief systems, cognitive biases, and pseudoscience). Importantly however, this does not mean that such ideas are necessarily true. A scientific idea is not true just because it is being proposed by a scientist, or has emerged from tests carried out in a laboratory. However, what it does mean is that such ideas are certainly more likely to be true, or more likely to be closer to the truth. There are no guarantees that any evidence or argument we accept as true will actually turn out to be true. Nevertheless, the appropriate application of the scientific method does provide an assurance that you have sound and justifiable reasons for accepting the claim as *provisionally* true.

The concept of all truth and theory being regarded as provisional is a fundamental and explicit aspect of science. Science acknowledges that theories exist in their current state only until more evidence leads to either a refinement of the existing theoretical model or the rejection of it. Therefore, and by definition, no particular theory can ever be regarded as the final word on the matter (though it can be regarded as the best current word on the matter). The explicit commitment to knowledge and 'truth' being provisional is of course in complete contrast to pseudoscience. Under these latter circumstances we are told that knowledge is final and cannot be questioned. Here, facts are twisted to fit pre-existing belief systems that cannot, indeed must not, be challenged. These beliefs require only that the individual accepts them in an unquestioned manner. In contrast, science states clearly that facts and evidence are those things which do not disappear if we choose to stop believing them.

A scientific theory is an explanation or "version" for a particularly puzzling aspect of the world. The aim of any theory is to suggest the best way to understand the object of study at that time and based on the best evidence currently available. When it is realised that scientific knowledge is only ever regarded as provisional, that science constantly challenges the existing accepted understandings it produces, that knowledge is not 100% accurate but a close approximation, explicitly discloses its methods, and demands independent replication by valid procedures, the idea that science is rigid, inflexible and "closed minded" is clearly ridiculous! By making an explicit commitment to all knowledge being provisional (as opposed to unquestionable), it is clear that science is the most open-minded stance a knowledge system can take!

To summarise, the scientific method provides the methods and tools that lead to provisional understandings of the world. We can, on the basis of evidence, logic and reason, make a case for provisionally accepting any claim, or rejecting any claim. Science makes the explicit commitment that it is the evidence that matters – it will either support or refute the validity and soundness of any claim or theory and by doing so, progress further towards whatever the 'truth' is likely to be. Science is about being less wrong tomorrow than we are today.

Characteristics of a pseudoscience

Ideas that are non-testable.

A crucial problem with many pseudoscientific ideas is that they cannot be tested in any meaningful way. This can come about because what is being claimed is so nebulous and vague it is difficult to conceive of how one would test it. Also, such vagueness facilitates a legion of 'possible' interpretations where just about anything could be made to fit the outcome to support the original claim. If a claim or theory cannot be tested then it cannot be falsified and thus it violates a central principle of science (that of falsifiability: see Braithwaite, 2006; Carroll, 2004). If a theory cannot be falsified then no evidence can be

gleaned that would speak to the issue one way or the other – it is thus scientifically meaningless. Ideas that cannot be tested are no more right than there are completely wrong.

Verbose language and prose

One reason that theories from pseudoscience are vague and untestable is that the language used by the proponents is far too vacuous itself. This often results in a 'theory' that is so conceptually slippery it becomes difficult to identify what is actually being argued – or how one might test it. Due to their nebulous content, such practices also nearly always hide all sorts of circular reasoning errors. Over-complex words, phrases and over-long sentences are employed in an attempt to 'look' scientific and intelligent. Indeed, in pseudoscience the more scientific-type language employed, the more 'plausible' it appears to be. However, all this really accomplishes is confusion. Poorly defined terms like 'energy' 'resonance' 'quantum' 'nano' 'dimensions' are all used with no useful explicit definitions provided. They are meant to look scientific, to look respectable in order to add weight to an idea which is in reality both implausible and improbable. Poor writing often reflects poor thought and poor understanding. Whenever one encounters flowery and verbose language it is likely the authors / speakers do not fully understand what they are talking about. Verbose language is used to fill-in the gaps of knowledge by making it sound as if something profound and insightful is being said, when in fact the sentence rarely goes anywhere!

Conceptual hijacking

An increasing trend in contemporary pseudoscience is to hijack aspects from mainstream science in an attempt to appear more scientific. This is usually done with very new areas of science where the publics understanding (and that of scientists themselves), is low. Recent examples include areas like quantum mechanics and string theory from the field of Physics. Paranormal theories that hijack these areas (in an attempt to make their poor ideas look more plausible) are riddled with huge misunderstandings over these concepts. Conceptual hijacking plays on the public's lack of understanding and presents a twisted version of science that bares little reality to the truth.

Confirmation-bias (selective evidence)

Many people report a common perception of thinking about someone, when the phone then rings and the caller is the person they were thinking of. Is this strong evidence for a psychic ability between these people? The answer is no. It reflects a selective bias in memory and reason. Although we can remember the instances when this does happen (as they can be striking) we rarely remember the instances when it is not the person we were thinking of. Our memory is biased to place an emphasis on the 'hits' and ignore the 'misses'. In a similar manner, researchers can sometimes concentrate only on that evidence that is consistent with the argument being developed (the hits) and ignore other evidence which contradicts it (the misses). This is known as the confirmation bias (where we are biased to only notice observations that confirm our assumptions). The confirmation bias relies on a positive biased focus and weighting towards only that evidence which is consistent with the current belief or world-view, and a negative bias to ignore results that challenge the view. It may be impressive to see a dowser find water in a single trial, but this on its own does not mean dowsing works. When we run tests and see that on many trials the dowser failed to locate water the scant and periodic instances when they are successful no longer looks impressive.

Metaphorical / analogy driven thinking

Metaphors and analogies are essential to science and theory. Complex and more abstract areas of science rely particularly on metaphor and analogy to add clarity to knowledge and to communicate that knowledge. This is perfectly legitimate and indeed, to some extent,

unavoidable. In science, analogies and metaphors may emerge as useful ways to think about, describe, and explain objective facts and evidence. For example, psychologists have employed the metaphor of visual selective attention being like a 'spotlight' illuminating the relevant information out there in the world from the surrounding darkness of all that we ignore. In many respects this has proved a very fruitful metaphor guiding thinking in this area of study. The problem here is not the use of analogies or metaphor in scientific thinking, but the clear abuse of them.

The problem with pseudoscience is its use and over-reliance on metaphor as an argument in and of itself. Rather than employ metaphors and analogies as illustrations of scientific knowledge, pseudoscience employs analogies to deduce new conclusions and propose alternative truths. At this point it no longer becomes a mere illustration; it becomes an *argument by analogy* (or metaphor; Thouless, 1968). Quite often, the richer and more intuitively appealing the analogy, the more true the claim being made appears to be. This can occur to such an extent that the analogy becomes a potent mind-trap and dominates all thinking on this issue. This is an error. Scientific arguments should be based on evidence, not analogy. The role of analogy in science is for illustration and communication – it is not for basing a claim of provisional truth. All analogies provide a degree of similarity to that which it is being applied to – this is why they are recruited as an illustration. However, there is also much dissimilarity as well and this is often missed (again another form of selection-bias). Ultimately, every analogy and metaphor will cease to work so it is crucial that any argument is not solely dependent on the analogy for its claim as a truth. As Thouless (1968) goes on to point out;

"Even the most successful analogies in the history of science break down at some point. Analogies are a valuable guide as to what facts we may expect, but are never final evidence as to what we shall discover. A guide whose reliability is certain to give out at some point must obviously be accepted with caution. We can never feel certain of a conclusion which rests only on analogy, and we must always look for more direct proof" (Thouless, 1968; pp142-143)

In some cases the analogy has no direct relevance or implication for the case being argued (the fallacy of the *argument by irrelevant analogy; a special case of the non-sequiter type of fallacy*). For example, modern creationists and advocates of intelligent design use analogies drawn from human design and engineering to argue for similar patterns in nature. The implication by such a comparison is that a designer must have been involved in the creation of the universe. Here the fallacy is to use a metaphor and analogy of a 'known' designer (i.e., something humans have designed and built) to prove the case of a divine designer. This type of comparison is an irrelevance. In addition, a closer examination often reveals that most pseudoscientific ideas are almost totally purely metaphorical in nature, form and content. That is to say, there are no reliable data, no firm facts, or evidence – just metaphor. This basically amounts to little more than a nice story – though not necessarily a correct or true one.

A good example of an over-reliance on metaphor and analogy is the 'stone-tape' metaphor that parapsychologists have used to explain ghostly sightings. According to the stone-tape account, human 'energies' and actions are somehow recorded in the immediate atmosphere and stored in the stone of a building or room, which can then be played back 'somehow' in 'someway' as a ghostly manifestation at a later date. The metaphor here is the notion of the making and playing back of recordings. However, despite its popularity, there is no scientific evidence to support this idea – and there never has been. Indeed, it is not at all clear as to how such recordings could be made by stone, and how they could be played back. All we are told is that it can occur *'somehow'* in *'someway'* - even though no plausible physical mechanism exists. This is an example of an over-reliance on a metaphor to support

a non-scientific idea. The problem here is the analogy and metaphor itself can blind the untrained mind to the lack of actual facts and evidence present in the argument.

"The mere fact that the argument is in the form of an analogy is often enough to force the immediate irrational acceptance. There seems to be no other explanation of the extraordinary extent to which otherwise intelligent people become convinced of highly improbable things because they have heard them supported by an analogy whose unsoundness should be apparent to an imbecile" (Thouless, 1968; pp146)

Anecdotes as evidence

Although anecdotal evidence has its place in scientific theory: no theory should be solely dependent on anecdotal evidence. Anecdotal evidence is a poor and unreliable source of evidence. For example, it is important that any theory of memory can explain the anecdotal experience of forgetting, but this should not just be based on anecdotes of forgetting, but on empirical demonstrations of the failure to retain information under controlled conditions. This leads to reliable and valid data on which to build a scientific account for the object of study. Similarly, theories of language need to be able to explain tip-of-the-tongue experiences (where we feel as if what we want to say is just failing to reach our ability to actually say it), slips of the tongue experiences (where we say a related word instead of the one we meant). However, the anecdotal experience of these instances does nothing to explain why and how they actually occur. These experiences are the products of psychological processes; however these products do nothing to explain the underlying processes themselves. Knowing that we have the phenomenal experience of consciousness, does not explain what consciousness is, or how it occurs.

One major problem with pseudoscience is that it places a strong and selective emphasis on anecdotes, and anecdotes alone, as support for its claims and theories. In reality, personal anecdotes alone are not a viable argument against data, facts, theory, empirical observation, and objective measurement. Lots of anecdotes do not support a case any more than a few anecdotes do. This is because all anecdotes are provided via a process which is itself fallible and prone to many sources of error. Anecdotal evidence has its place in scientific theory - but it is no contender for a source of information which can provide a mechanistic understanding the mental universe. Contrary to the popular saying, *data* is not the plural of *anecdote*.

Lack of explicit mechanisms

Pseudoscience is characterised by a complete lack of viable explicit mechanisms of action for the object being studied. Even if we were to accept some instances as fact, there is still no clear idea how these phenomena would work or how they could work. There is no clear and plausible proposed mechanism for how apparitions are supposed to be recorded in stone, no clear mechanism for how astrology is supposed to influence human behaviour, no clear mechanism for how the mind could survive bodily death or how liquids can hold a memory (as is claimed in homeopathy). This lack of explicitness is related to some of the other characteristics listed above. For example, the fact that an idea is nebulous in turn makes it difficult to test such ideas (i.e., cannot be falsified). Furthermore, an idea can be nebulous due to verbose language (see above). However, even when these factors are not a major concern there is still a lack of a workable explicit mechanism. Even the best and clearest explanations of homeopathy, apparitions, alternative health, and psychic phenomena still fail badly at outlining a specific mechanism for how they are supposed to work. Although the lack of any mechanism is not, in itself, evidence against the existence of such phenomena occurring, the lack of any plausible mechanism waiting verification is not particularly convincing evidence for it being genuine either. There are many areas of experimental science where mechanisms of action are not well understood – however, under these

circumstances there will be some factual and accepted knowledge that provides a framework for thinking. In addition, although a mechanism may not be known, candidate mechanisms will be well specified to a level that guides future experimentation and thinking. What counts in science is the ability for a provisional explanation to feasibly account for the phenomena via a proposed mechanism that is more explicit than any other. An explicit mechanism should also generate clear predictions and these predictions should be testable (and falsifiable). The mechanism should say *why* the phenomenon occurs, *what* the principal components are, *how* it works, and *what* it does.

In contrast to scientific mechanisms and models, Parapsychology has been actively investigating paranormal and psychic phenomena since the 1940s – and yet despite the decades that have passed, no reliable evidence, or explicit and plausible mechanism has ever been proposed that suggests paranormal phenomena are a real veridical objective event.

The seven fallacies of thought and reason

There are many forms of logical fallacy, errors, and mistakes of reason. In addition to this many fallacies co-exist and network together in yet further complex combinations. The net consequence of this is a conviction and feeling of coherence in the views being held – a sense of things making sense! This feeling of 'everything making sense' in the absence of any evidence, logic or reason, is an illusion based in the collective impact of unstructured thought. The level of the delusion is often far greater than the sum of its underlying parts. A good deal of these fallacies lie outside the scope of the present paper, for a more comprehensive discussion the reader is directed towards more substantial texts in this field (i.e., Browne & Keeley, 2003; Carroll, 2004; Shermer, 2002). The mistakes of thought and reason listed here have been chosen and highlighted on basis that they are the most common. Therefore, these errors are so prevalent, they have permeated and perverted the public's perception of science the most. The seven main fallacies are listed here in reverse order. The order generally relates to the popularity and persuasiveness of that fallacy in general popular science and pseudoscience, with number 7 being the lesser and number 1 being the most popular forms of fallacious thinking and argument. The combined outcome of accepting these fallacies is the same – they all lead to error in thinking. All represent mind-traps in thinking that lead ultimately to either unsound thinking or a completely fictitious characterisation of science and the processes of legitimate scientific argumentation.

(7) I am entitled to my opinion (used to support the truth of the opinion).

A quite common outcome in arguments between science and pseudoscience is when the person holding the failing position resorts to saying *"...well, that is my view and I am entitled to my opinion."* This is often recruited in support of the argument being made, thus implying that ones entitlement is somehow important for the truth of the argument itself. Indeed they are entitled to their opinion, but their entitlements were never in question. We are all entitled to our opinions – but this has no consequence for the scientific truth of them and does not establish or justify the validity of them. So the problem here arises when one recruits the mere 'entitlement' (and no evidence) to a view, as some form of evidential support for the truth of the view. It is often used as a final defence mechanism when faced with quite strong counter-arguments and evidence.

The crucial point with this error in argumentation is that your individual entitlement to hold a view is no indication at all as to its validity or truth – indeed, it is completely irrelevant (a form of the non-sequiter fallacy). When having a scientific debate, discussing evidence and theory, it makes no sense to recruit your human rights and 'entitlements' in defence of any view. It shifts the focus from one of science, evidence, and reason to one of human rights (see Whyte, 2005). This is an irrelevant and unhelpful tangent. You are of

course entitled to hold any view you please, but it becomes a fallacy of reason to recruit that mere entitlement as some form of evidence in support of the truth of that view. Recruiting the 'I'm entitled to my opinion' stance in any debate is functionally equivalent to saying, 'I am entitled to be wrong!' Entitlements do not establish truth. Human entitlements and rights are irrelevant to a scientific debate based on facts, evidence and reason. A scientist may be entitled to his / her opinion of the facts, but their entitlements do not make them correct, their data and evidence makes them correct. A scientist is entitled to believe that the boiling point of water is 100 degrees Celsius, but the entitlement to that view does not make the scientist correct – the facts gained from scientific study provide evidence – which actually exists independent of anyone's view of it. Therefore, it is sound reasoning, logic, and the recruitment of supportive empirical evidence of quality that makes an argument more likely to be correct.

(6) Argumentum Ad-hominem: Shoot the messenger fallacy.

This is a common logical fallacy. Argumentum ad hominem basically means that the argument becomes directed towards the individual as opposed towards the crucial issues being discussed. It is succinctly described as, attack the messenger not the message (hence – shoot the messenger). It is often seen in both politics and pseudoscience. Its aim is to undermine the position of ones opponent, by undermining the opponent personally (in a manner that is actually completely irrelevant to the debate). The hope here is that if one can discredit the individual, this by default, discredits his / her argument. It does not. The fallacy here relates to the irrelevance of the attack. It is not viable to argue against a position and then justify that argument by criticising the individual who holds it. Arguing that the proposals from the Educational minister are unlikely to work because he / she have no children of their own is hardly convincing. Furthermore, saying that Einstein or Darwin were selfish men does nothing to discredit the theories of Relativity and Evolution. They may have been the most selfish or the most unselfish of men, but this is an irrelevance as to the 'truth' of their scientific claims. Similarly, a cognitive neuroscientific account of strange experiences (i.e., near-death experiences) is not incorrect simply because the scientist proposing it is a skeptic. These are all examples of the ad-hominem fallacy. Any claim or theory should not be rejected solely on the basis of who holds it.

(5) I'm offended! (A special case of the red-herring fallacy)

When a core belief is under threat from a good counter-argument it is common for many to defend the belief by stating "I'm offended". Here the person whose beliefs are under threat seeks to defend their position and thinking, not with evidence and argument, but by throwing out an often unjustified comment claiming to be offended. Creationists get offended by Evolutionary theory, Parapsychologists get offended by more sceptical scientific interpretations, and Pseudoscientists get offended when their unfounded premises and illogical cherished ideas are called into question. None of this of course, means that the beliefs of the individual being offended are actually true. It means nothing and can be cast as an instance of (i) the red-herring fallacy (evading the issue via diversion) (ii) to some degree the non-sequiter fallacy (where the argument does not follow from the premise, or the conclusion does not follow from the argument), and / or (iii) the irrelevant objection fallacy (where the completely irrelevant tangent of being offended is recruited as an objection to the argument). The problem is the 'I'm offended' card gets played far too easily for those whose position is difficult to defend. It is often recruited even when an opponent in a debate makes a perfectly reasonable suggestion or asks a respectful but challenging question.

Playing the 'I'm offended' card every time the debate gets interesting is neither a well reasoned, sensible or scientific position to take. It has no place in an adult intelligent debate about the issues. The perception comes about because to question a core belief of someone

is, to them, to question them personally. It is not and nothing could be further from the truth. This 'red herring' fallacy is an attempt to steer attention away from the real crux of the issue that many find difficult to deal with. It liberates such individuals from having to justify and support their argument. If you say 'I am offended' then that's all you need to say and in the minds of such people it gets them out of having to consider the issues at hand. It is a sort of cognitive defence mechanism - that serves to protect the belief position of the person. It seems their position really is – "I *get offended by anything I do not agree with"* - how can this be a viable position for a reasoned argument on science?

(4) Science cannot explain everything and does not have all the answers.

This argument goes something like – as science cannot explain everything and does not have all the answers, it follows that (i) science is limited and (ii) other answers from other knowledge systems could be true (i.e., belief-systems and pseudoscience). Or to put it another way, science is limited and those very limitations stop it from answering specific questions concerning certain issues. This is then typically used to gain leverage for claiming a 'truth' via these other knowledge systems (typically ones that don't employ the principles of science). Common examples would be debates on psychic abilities, the existence of an after-life and the existence of apparitions from areas like parapsychology and popular science.

There are a number of reasons for why this argument is a falsehood. Firstly, science never claims to have all the answers – just a reliable and useful method for revealing them. So attacking science for not having all the answers is something of a straw-man argument in the first place (blaming science for not being able to do something – it never claimed to be able to do in the first place!). Secondly, the argument is based in the assumption that the limitations of science actually have any implications for what is being proposed. Although science is indeed limited, it does not automatically follow that these limitations have any implications for the existence of certain phenomena (i.e., of paranormal phenomena). The problem here relates to the idea that the limitations of science have any bearing whatsoever on the failure to find any evidence for, say, paranormal phenomena. However, if Extra-Sensory Perception (ESP) exists, a relatively simple science of mathematical probabilities, chance expectancies and well controlled experiments would be able to demonstrate its existence. The same would hold for other claimed abilities (mind reading, psycho-kinesis, mediumship, dowsing, remote viewing, etc). Science has had techniques and methodologies at its disposal for many years that are more than suitable to test and refute (or establish) such claims. A relatively basic and simple well-controlled science would be more than sufficient to establish the truth of these claims. Thirdly, the limitations of one knowledge system do not, by default, add credence or support to any alternative. That is, although science may well be limited, this does not mean that alternative knowledge systems have any additional merits by default. For instance, gaps in knowledge from Astronomical science do not mean we should abandon it for Astrology. For Astrology to be a viable alternative it would need to demonstrate its own credentials for knowledge and understanding, independently of the limitations of any other system. The fact that science does not have all the answers, does not mean that pseudoscience has any answers at all (or is indeed capable of ever producing any)! This is the crucial delusion underlying this argument. On this basis, the argument is meaningless.

(3) Science is often wrong, and has been shown to be wrong before, therefore it could be wrong about the paranormal.

A common argument against science is that, it has been wrong before – so it could be wrong again and also about issues that pseudoscience promotes. Despite popular opinion, science is not about absolutes and definite proof. Science deals with the most plausible, probable and likely explanations based on the evidence available at any given time (i.e., it is

probabilistic). As noted earlier, science makes the explicit commitment that any scientific truth is provisional and although any account may turn out to be false in the future, it may be the best account in the present. The underling thought processes at work in pseudoscience play on the notion of science being about probable truth (as opposed absolute truth) as a weakness. Once the idea of a weakness in science is proposed, it is a small step to further claim the lack of absolutes implies that no theory can be considered completely 'true' and thus, could be totally wrong. Furthermore, as scientific ideas are not 100% true; then pseudo-logic states that (i) any idea could be a viable alternative to the scientific theory and (ii) all existing ideas are equally valid and equally true. Herein lay the fallacies of this argument.

In reality the explicit commitment of science being about provisional truth is actually a strength. It is an open commitment to knowledge never being infallible. There are many complex areas of inquiry and finding answers is not easy. Initial ideas and hypotheses may be quite wrong; however, where they are shown to be wrong, they will be amended and retested. Via this process, we get closer to what is true every step of the way by being *less wrong than before*. To argue that science cannot prove things to be 100% true is fine, but for people to use it as an argument to give validity to completely untenable ideas is fallacious. Pseudoscientific ideas can be quite wrong for reasons that have nothing to do with the limitations of science. Both pseudoscience and science may be wrong; but science is highly likely to be far less wrong than pseudoscience.

Let us examine the initial notion of science having been wrong before (as this is the basis underlying this argument). Science has indeed been wrong before. Science is not 100% foolproof and it has never claimed to be perfect. Sometimes ideas need refinement and sometimes ideas require a complete refutation. However, this is not a weakness or a fault of science. Indeed, it is a fundamental and accepted part of the process of science as it discovers provisional truths. As science explicitly acknowledges that all knowledge is provisional, this makes it clear that current knowledge can be, and indeed should be, constantly revised if it is necessary to do so. Crucially however, the errors in science are not revealed to the educated world by pseudoscience! Science identifies the errors in scientific knowledge in the first place. This highlights an important aspect of science – that is, it is self-policing. Fraud, error and mistake, if they occur, will be discovered. The process of science identifies and corrects its own mistakes.

Pseudoscience also makes a fundamental contradiction here in relation to its argument. Pseudoscience criticises science for prior mistakes – but uses the new knowledge produced by science to attack earlier scientific ideas. From this position it attacks science itself. This is odd when one realises that the new knowledge which pseudoscience tries to employ in its argument was not produced by pseudoscience, but was actually produced by the very system pseudoscience seeks to attack and undermine! That is, it uses new science to attack old science and then attack the whole process of science itself. Pseudoscience also fails to understand that older ideas, which may have been incomplete, aid newer and more comprehensive ideas. There can be far less friction between new ideas and older ones than pseudoscience would have you believe.

A further failing in this argument against science is that although science may well have been wrong before, this does not mean that pseudoscience has ever been correct ever! That is to say, the limitations of science do not, by default, provide support for any form of pseudoscience. To be a viable source of knowledge and understanding, pseudoscience requires its own merits.

(2) Science cannot disprove the paranormal – therefore, this failure is, by default, support for the existence of paranormal phenomena.

This is a fundamental misunderstanding of a number of central principles of science. It reflects a variety of logical fallacies and mistakes of reason. These include (i) argumentum ad ignorantiam, (ii) a misunderstanding of the difference between the evidence or absence and the absence of evidence, (iii) a misunderstanding of the principles of falsifiability and sufficiency, (iv) a shifting of the burden of proof. These, along with other contextual issues are discussed below.

Argumentum ad ignorantiam basically means the *argument to ignorance*. The underlying fallacy from the argument to ignorance is when it is argued that something must be true, purely and simply because it has not been proved to be false (or vice versa). Carroll (2004) suggests, this fallacy could also be called the *"fallacy from lack of sufficient evidence to the contrary"* (Carroll, 2004; pp115). The fallacy of the argument to ignorance is not based in any one individual in an argument being ignorant – it is thus not directed to the individual. The notion of ignorance relates to the form of the argument itself. In this case, to there being 'no evidence' and thus, we are ignorant of the potential truth. The crucial point to keep in mind here is that an inability to disprove a claim does not automatically mean that the claim being made is true. An individual might make the claim that he / she can run the 100 metres sprint in under seven seconds (which would be the fastest ever recorded). However, if the person refuses to be tested in a race, our inability to falsify the claim does not make the claim true by default. If this was the case, anybody making a claim like this would be eligible for an Olympic gold medal, without ever having to run a single race! A similar fallacious argument to ignorance would be one that states *"as nobody can prove God did not create the universe, it must therefore be true".* The lack of evidence means nothing either way. The fallacy also works in the other direction as well. For example, a statement like; *"Of course apparitions do not exist, nobody has provided any proof that they are indeed real"* is also an error in reasoning committing the same fallacy. In science, we can make the valid assumption that from the lack of evidence, something has not occurred. However, we cannot conclude with absolute certainty that it has not occurred.

One mistake related to the argument to ignorance is to falsely interpret the absence of evidence as being equal to that of there being evidence of absence. Clearly they are not equal. The crucial point is that although science may not be able to disprove a claim, this is not evidence in support of the claim. Science accepts claims, not just on the basis of the absence of evidence but mainly on the presence of confirming evidence (i.e., positive evidence). There must be positive empirical evidence for accepting any claim or argument as being true. The lack of any evidence itself is not direct support of an alternative paranormal theory. It is completely neutral on the matter. The absence of evidence for Creationism does not, on its own, provide support for the theory of Evolution. The theory of Evolution requires its own positive evidence to establish it as a truth. The confusion over the absence of evidence being the same as evidence of absence is also related to some misunderstandings over the notion of falsification in science.

The principal of falsifiability states that in order for any claim to be held as a scientific truth – it must be falsifiable. That is to say, we must be able to test it and falsify it. The rule of falsifiability is an assurance that if the claim being made is indeed false, then the evidence will show it is false; and if the claim is true, then the evidence will not disprove it. In the latter case we can accept the claim as a provisional account of 'truth' until such time as further evidence is produced which disproves it (thus, it is a provisional truth). Therefore, the rule of falsifiability makes the explicit commitment that the evidence must matter and has to matter in a well reasoned scientific argument. If we cannot test the claim being made then that claim is no more true, than it is false. The problem with pseudoscience is that many of their claims are not testable – yet this absence of evidence is often taken as direct support for the claim. As noted above, if the absence of disconfirming evidence were to be

taken as proof for a claim, then it is conceivable that we could show anything to be true – even when it is totally false. In addition to this, Lett (1990) notes, this type of faulty reasoning is also related to the concept of 'sufficiency'. That is to say, any evidence recruited in support of a claim must be sufficient to establish the truth of that claim, in the manner in which it was made. The absence of disconfirming evidence for a particular claim, is not sufficient on its own to establish the truth of that claim. This type of reasoning is also relevant to a related error, that of it being up to science to disprove the existence of the paranormal. The discussion above shows clearly why this type of reasoning is incorrect and not a viable criticism of science at all.

Finally, another error in reasoning underlying these types of arguments relates to the burden of proof. It is not the job of science to disprove such claims (any claims). Indeed, science maintains that this is logically impossible. The burden of proof always rests with those making the claims. In other words the claimant must furnish the claim with good quality evidence, reason and logic. If a scientist argues that all species evolve through a process of natural selection, then he / she needs to support that claim with positive evidence for that process. If a parapsychologist argues that the mind is separate from the brain and can survive bodily death, then he / she also needs to support that claim with positive evidence. It is unsound to argue that the absence of evidence alone, due to (i) a failure of science disproving claims and (ii) shifting the burden of proof onto others, somehow supports the claim being made. The burden of providing positive evidence lies with those making the claims.

(1) Scientists and skeptics are closed-minded and are not open to other possibilities (not open-minded).

This is by far, the most perverse, corrosive, and commonly touted criticism that the ill-informed direct towards mainstream science. The underlying idea is that scientists are too strict and constrained in their thinking. By this account, science is seen as rigid and unforgiving. The basic suggestion being made is that scientists themselves are supposed to be so 'closed-minded' that they will not 'open their minds' to other possibilities[3]. As a viable argument against science it is an irrelevance and a folly. This claim can occur for a variety of reasons and reflects a number of diverse errors in thinking and reason. Before the fundamental fallacies of this type of argument against science are addressed it is important to consider just what being open-minded really means (as opposed to what pseudoscience would like it to mean).

In contrast to popular opinion, being open-minded does not mean considering all and every possibility as equally viable. This is impractical and besides, many ideas and claims are completely unsupported by the evidence or are also simply ridiculous. Should we view the idea that homeopathy can cure illnesses, as being evidentially equivalent to that of mainstream medicine? The claim that the earth is flat is not as valid and evidenced as the fact that it is round – so why should we view them as equal? Is the idea that aliens may have abducted someone in the night and then returned them as equally plausible as the idea that maybe they dreamt it? For all these instances, the current evidence suggests a clear answer – no! All ideas are not equally valid, ideas that are supported by reason, and more evidence of a higher quality are more probable and more relevant than those ideas that have neither. Once acknowledged we can see that one of the main claims of pseudoscience; that of all ideas being equally valid, is clearly ridiculous. The fundamental mistake of pseudoscience is to misrepresent and misunderstand what being open-minded really means.

[3] The implication here is that these *'other possibilities'* are actually *'paranormal possibilities'*.

Therefore, being open-minded certainly does not mean accepting all manner of claims and weird ideas equally. It is not the case that all ideas and claims have equal evidential weight. To accept claims uncritically, in the absence of supporting evidence, has nothing to do with being open-minded. Accepting claims purely on the basis of belief and wishful thinking is to be credulous. Open-mindedness is often confused for credulity; the two are not the same thing. The implicit theme running through this line of fallacious argument generates a kind of false argument in that if scientists and sceptics do not endorse and embrace pseudoscientific arguments as true, this is because they must be 'closed-minded' (as opposed to the more likely explanation of the argument simply being false).

What pseudoscience fails to acknowledge is that to be truly open-minded, the researcher must entertain and consider the possibility that an idea may be true, and entertain the possibility that an idea may be completely false. Therefore, open-mindedness means the researcher is open to both possibilities! There is nothing closed minded about openly and objectively considering an idea or claim and then rejecting it. Pseudoscience seems to see open-mindedness as the uncritical acceptance of unsupported claims and ideas; to accept that which they hope is true, as opposed to that which is more likely to be true. Pseudoscience basically states that any idea should be accepted with an 'open-mind' and thus, such acceptance indexes an open mind. Clearly it does not. Pseudoscience completely fails to entertain the possibility that science has considered their suggestions, claims and arguments and merely rejected them in a fair and reasoned manner. Pseudoscience does not realise that the views of science are actually based on a considered approach. Scientists have done nothing wrong other than to back the idea with the highest quality evidence, supporting the most reasoned and the most likely account.

The reality is that science deals with the most probable and most plausible arguments and claims. Such plausibility and probability emerges through the existence of empirical data, objective facts, evidence, logic and reason. This process does not result in closed-mindedness to other possibilities, but open-mindedness to all plausible probabilities. That is to say, it results in open-mindedness to the most likely and true explanations. Being an open-minded person means considering ideas and arguments on these criteria. If the argument or claim being made can be shown to be correct, then an open-minded person will modify their views accordingly – indeed science would demand this in the face of good quality evidence. If the argument is found wanting in a number of fundamental aspects, it will be soundly rejected and with good reason.

Another problem with the ‘closed-minded’ argument against science is that it is a form of generic ad-hominem fallacy. However, instead of being directed at one person, it attacks a whole system of thought as opposed to dealing with the testable and refutable knowledge and understanding it generates. This charge is usually made by those who cannot provide any high quality data for their pet-theories or do not like the high-quality evidence science has produced. The net consequence is to attack science itself as a system of knowledge. It is also often applied in and an ad-hoc manner, where the scientist is only categorised as being closed-minded when it becomes clear they do not concur or support the position of the pseudoscientist. It has nothing to do with whether the scientist has good reason to disagree, or has evidence of a higher quality that comes to a different conclusion – the ‘close-minded’ claim gets touted simply because the pet-theory of the pseudoscientist is soundly refuted. Attacking science in this manner is an irrelevance. It is also a debating technique to shift the arguments away from the fact pseudoscience has no objective evidence or sound underlying logic. In other words, it is an attempt to hide the fact that pseudoscience struggles to produce evidence. The closed-minded argument is also a form of straw-man argument. Like all the other fallacies listed in this paper, the closed-minded claim attacks an incorrect representation of science and what being open-minded really is. This makes it easier for the pseudoscience to attack science – but in reality what they are attacking, is not the reality of science, but their straw-man which is easier to knock down.

To summarise, the objective nature of science, the acknowledgement of all scientific knowledge being regarded as provisional, the explicit methods and need for independent replication, clearly show that the process of science is indeed open-minded. In contrast to the common perception, science is not about debunking ideas and rejecting claims out of hand; it is about investigating them in a serious, sensible, and reliable manner. The explicit acknowledgement to scientific knowledge being provisional is of course in complete contrast to a belief-system or pseudoscience. Under these latter circumstances any knowledge is final, fits with pre-existing belief, is biased, swayed by irrelevant emotions and wishful thinking, cannot be questioned, and must be accepted. These beliefs require only that the individual accept them in an unquestioned manner. However, for science all knowledge is open to be independently evaluated, tested, confirmed, revised or rejected. It is somewhat ironic that belief-systems and pseudoscience charge science with being "closed minded"! Clearly, by making an explicit commitment to all knowledge being provisional (as opposed to unquestionable), this is the most open-minded stance any knowledge system can take.

Discussion

In recent years, pseudoscience has sought to undermine scientific knowledge by attacking science itself. This has led to a growing misperception amongst members of the public and some science students about what science is and how it does what it does. Many myths are propagated by popular science and pseudoscience with the explicit intention of undermining science. This paper has outlined what are perhaps some of the most popular and common arguments gaining currency in the public domain. These errors are united by both their fallacious form and the misrepresentation of the science they seek to attack. Science may not be perfect, but it is the best system we have. Pseudoscience has nothing to offer in terms of scientific truth and understanding. It seeks to delude and provide false hope. In contrast, science tackles how things are, not how we want them to be. This paper has highlighted potent errors in argument from pseudoscience with the aim of showing clearly why they simply do not work as viable challenges to science.

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