Critical Thinking, Logic and Reason: A Practical Guide for Students and Academics

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Overview: Thinking critically, clearly, and effectively is not an easy process. Critical thinking is not a natural way to reason about the world. These skills, like any other, require considerable thought, effort and practise. It is both surprising and unfortunate that few academic Universities actually provide students with explicit courses directed at developing critical thinking skills and the tools of logic and reason. Contemporary university courses tend to concentrate on teaching students "*what*" to think and not "*how*" to think. Despite their intelligence, many students and researchers often fail dramatically at knowing how to construct a well reasoned and logical argument. This document is a practical guide for both students and academics to improve their critical thinking skills. This practical guide will help readers think more effectively about their own research and about the research of others. For students, this guide is a welcome aid for reading publications and evaluating claims. Developing critical thinking skills will also improve the student's performance at writing cogent essays, clear laboratory reports and answering exam questions more effectively.

Introduction:

It does not automatically follow that being intelligent means the student can think critically or reason about information in a useful, effective and efficient manner. Many very intelligent people hold very odd and somewhat irrational beliefs about the world. Being smart and intelligent is simply not enough. Critical thinking is a process. It is a journey that helps us to arrive at the most useful, helpful, and most likely destinations when evaluating claims for scientific truth. Critical thinking is thinking clearly, thinking fairly, thinking rationally, thinking objectively, and thinking independently. It is a process that hopefully leads to an impartial investigation of the data and facts that remains unswayed by irrelevant emotions. The aim is to arrive at well reasoned, considered, and justifiable conclusions. Thinking critically is an ability to engage with the evidence, to consider and to evaluate the evidence (the type of evidence, the quality of evidence, etc) from multiple and relevant competing sources.

Ideas that have come through scientific inquiry and the processes of critical thinking are more likely to stand on firmer ground relative to other ideas that have emerged through less rational processes (i.e., belief systems, cognitive biases, and pseudoscience). Note however, that this does not mean that such ideas are necessarily correct or true, just that they are more likely to be so. It is a game of probabilities and not one of absolutes. There are no guarantees that any evidence or argument we accept as true actually will turn out to be true. However, if you apply the principles of critical thinking in an appropriate manner, it does guarantee that you have good and justifiable reasons for accepting the claim.

Although critical thinking (and all that goes with it) is intrinsic to the scientific method – it is a more general process than science itself and can be applied to all forms of knowledge which ask us to accept them as being true. Critical thinking is just as important to the home buyer trying to select the right mortgage, to the voter trying to choose the most appropriate political candidate, and the applicant trying to choose the right career path, as it is to the student trying to evaluate an argument and write a first-class essay or the scientist trying to develop a new theory.

In addition, there are many arguments from the real-world which may require us to apply free and independent thinking to them. Popular examples from recent media-frenzied interest include; (i) the link between the MMR vaccine and autism in children, (ii) the use of mobile phones and the link to brain cancer from electromagnetic fields. It might come as a surprise to the reader that, at the time of writing, there is no direct scientific evidence to support any of these popular media myths. The best controlled studies, drawing on the largest samples, using the most methodologically appropriate techniques, have all failed to establish a clear link between these factors. Of course, much more research is needed – but the idea that a link has been established between these factors betrays the true level of the current evidence – despite what pressure groups might want you to believe! These examples show that the need for clear, rational and critical thought is all around us and not just restricted to the laboratory.

Common sense notions of the world and the need / purpose for critical thinking, science, & reason

To decide whether to hold particular opinions / views or not, we have to consider only whether they are true! However, many ideas and theories claim to be true or provide some accurate account of the data and evidence. Claims can come from many sources; can vary in scope, credence, and support. For instance, Creationism claims that the world was built in six days, and the universe is around 5000 – 6000 years old. Indeed modern Creationism claims to be a valid counter-argument to the theory of Evolution and as such, is explicitly claiming to be factually correct. This becomes more of a problem of mere beliefs when Creationists start to argue that their beliefs are logically equivalent to the scientific counter arguments.[1] In other words, Creationism argues that it is a theory with as much credence and support as Evolution. The problem is – how do we decide which account is more likely to be true?

Many 'common-sense' notions of the world also often claim to be factually correct. The problem with common sense notions is that they are persuasive, based on intuition, anecdotal assumptions and habits of thought. Many are very widespread, despite being totally incorrect.

For example, there is a very popular common-sense belief that we humans only use 10% of our brains. This belief has been developed and propagated by alternative and new-age health practitioners, who then also go on to market their products for 'expanding' the human mind into the unused 90%. It is claimed that by adopting and buying into such methods we can all realise our full potential (see Beyerstein, 1999; for an excellent review). Neuroscience suggests something quite different. Faced with such diverse claims, how do we know which account is more likely to be correct? To address this, we need a system of thought based in data, facts, evidence and reason to decide whom to believe and what to accept. We need a helpful way of evaluating factual claims to see if they are likely to be true. Critical thinking questions these common-sense notions by checking the facts in an objective manner.

Let us re-examine the claim that we only use 10% of our brains as an example of how useful critical thinking and scientific reasoning can be. To show why this idea is inaccurate we need to think critically about it (don't just take my word for it!).

[1] These points are not directed against the principle of holding a belief or the existence of belief-systems per-se, but only against belief-systems that claim to be scientific truths and thus rival scientific knowledge.

Firstly, the argument needs to be characterised appropriately. The claim is that we only use 10% of our brains. Or, to look at it another way, the claim is that 90% of our brain is totally redundant! This is the essence of the argument. Secondly, having now characterised the argument, we can ask – is it true? What is the evidence in support of it? What is the evidence against it? Does it make sense?

Let us first consider evidence from cognitive neuropsychology. Brain-damaged patient studies clearly show that severe cognitive impairment can result from damage to any part of the human brain. Indeed even relatively minor and localised damage can have a huge impact on cognition. Surely, if we only use 10% of our brains (thus rendering 90% of the brain as being functionally redundant) then there should be many brain regions that could sustain wide-spread organic damage without any form of cognitive impairment occurring. Clearly this is not the case. Furthermore, the suggestion that we only use 10% of our brain seems to suggest that we can function quite well if 90% of it is completely removed!

There are other good reasons for doubting this claim. From an evolutionary perspective, it is not clear why humans developed such a large organ, to then only utilise 10% of it. This is even more striking when it is realised that the brain is a very costly thing to run in terms of its oxygen and nutrient requirements. If we are only using 10% of the brain, why would evolution allow us to develop such an inefficient organ which clearly has such high fuel consumption? Also, what is all that fuel doing if we are only using 10% of the brain? Would this not predict a more economical use of resources than is the case?

There are still further problems for the 10% claim. Functional scans from brain-imaging studies have clearly shown that cognitive functions depend on highly interconnected and distributed neural processes that can extend across large sections of the outer cortex alone (irrespective of sub-cortical contributions as well). In addition to this, the observation that many cognitive functions take place largely in separate locations across the brain shows clearly that no part of the brain is truly inactive or uninvolved in human performance.

Finally, as Beyerstein (1999) points out, despite the popularity of this myth and the claims of pseudo-scientists, there is no publication in the field of neuroscience that reports the apparent fact that humans only use 10% of their brains (and there never has been). When the 10% claim is evaluated and viewed in light of these multiple observations the claim appears to be at the least totally inaccurate, and at most, ridiculous.

What these above examples show is that common-sense notions of the world are not equipped to reveal valid truth and sound understanding. Indeed, often quite the opposite. This is a really good example of how popular ideas and so called common-sense notions are inadequate at generating accurate or even plausible explanations. This example also shows that simply looking at many claims and thinking them through clearly, can show them to be totally inadequate as plausible accounts. An idea is no more true simply because lots of people believe it to be true.

Why is critical thinking a skill that has to be learnt and not a pure natural ability?

Our brains are naturally biased to handle information in a particular and somewhat automatic way. 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 persuasive but are in fact false and incorrect. These predispositions are known as, cognitive biases, habits of thought, or heuristics (mental rules of thumb). A good example is the gambler's fallacy. Imagine a gambler playing roulette in a casino. Imagine he bets on black, and it comes up red. Furthermore, it comes up red a further four times. The gambler may decide to stick with black as, according to our natural biases, it seems perfectly reasonable to assume that a sequence of reds occurring means a new 'black' number is due anytime. This is in fact completely untrue. Each spin of the roulette wheel is a new event where the red and black numbers have an equal and fixed probability of occurring. What happened over recent spins has absolutely no consequence for the new spin as the ball and wheel have no memory! The idea that what has happened before, will impact again in the future (on a truly random event) is the gamblers fallacy based in a cognitive illusion known as the illusion of sequential dependency. Indeed, if we entered the casino and were offered the knowledge of the outcomes from the last ten spins of the roulette wheel – we would probably want that information before gambling. For the same reasons – this information is meaningless and has no bearing on subsequent outcomes (even though it 'feels' like it helps us).

Think of the national lottery. Many people choose numbers that are meaningful to them (i.e., a birthday, anniversary, house number, etc). Studies have shown that many people are reluctant to swap their numbers for random lucky dips, as they feel these meaningful numbers have a better chance of winning. This is of course, completely false. The lottery is a completely random process and no numbers are more likely relative to any others. Sticking with the lottery theme, another interesting observation is that many people choose numbers right across the range. For instance, it is common to choose a number from 1 to 9, then from 10 to 20, from 20 to 30, and so on. This is based in the perception that chance is somehow evenly represented across the nominal numbers. This is also false. Chance is blind to the numbers and there is nothing stopping a sequence in numerical order occurring (i.e., 5, 6, 7, 8, etc). Indeed, this is exactly what happens on roll-over weeks when no one seems to have selected the chance behaviour of the outcome. Our perception of truly random and chance events is heavily biased and contorted. Humans are very bad at being intuitive statisticians!

These biases, which seem perfectly reasonable at first glance, are the inherent biases that steer our thinking. As you can see from these examples, unstructured and uninformed thinking may appear reasonable at first glance, but may actually be far from it. This is why we need to think critically and think scientifically. The tools of critical thinking often go against these natural biases, and most of us have to learn them and master them over time. It fights against the initial biases we all have that seem to want to 'jump to an immediate conclusion' which may actually lead us to arrive at a conclusion or opinion that is false. Thinking critically is the total opposite of thinking naturally. Students may well find it hard at first but once we have decided to make the effort, thinking critically becomes easier with practice and it is worth it.

What looks like critical thinking but is not

Contrary to popular opinion thinking critically does not mean simply rejecting any evidence and argument without consideration. Critical thinking does not mean being argumentative just for the sake of it or simply refusing all attempts by others to convince you of their arguments. It does not follow that the best critical thinkers are the ones which are most critical of everything! Indeed, to accept no theoretical position at all makes as little a contribution to knowledge as simply accepting any idea based on illogical and unreasonable grounds. In other words, a scientist that is so critical they accept or propose no firm theoretical viewpoint (because they refuse to accept any evidence) makes as little a contribution to knowledge and understanding as the fervent religious believer who spends no time with facts and evidence at all and accepts information based on unquestioned belief. Both extremes are unhelpful and are ultimately logically meaningless. In sum critical thinking is not about setting out to find faults with an argument, it is about arriving at a provisional truth (what ever it may be) and providing the most probable and plausible understanding for the evidence at that time. If a firm conclusion cannot be drawn (due to insufficient evidence etc) then critical thinking can still help to highlight which types of conclusions may turn out to be more likely depending on the type of evidence that may be discovered.

Part I: Background in critical thinking

Becoming a critical thinker

The decision to become a critical thinker, to continually question and challenge ones own ideas, and those of others, is an admirable one. To be an effective critical thinker the individual needs to possess and develop a number of thinking tools or faculties. It does not matter whether the critical thinker ultimately ends up agreeing with the arguments being made or disagreeing with them. As long as the decision is informed on data, facts, evidence, a reasoned and rational perspective, then the ideas and arguments have scientific merit and can be defended.

The critical thinker must approach any information with a certain degree of constructional doubt. Doubt must be applied in a constructional manner and not just for its own sake. It is neither helpful nor scientific to say *"I simply don't believe it, so there".* The critical thinker needs to be able to qualify and justify their criticisms and reservations with a well reasoned argument. It is also helpful to provide (or at least try to provide) plausible alternative interpretations of the evidence rather than simply show how certain arguments are flawed. All arguments might be limited in some ultimate sense – but not all these limitations may have logical implications for the arguments being made. This is something many students fail to notice in their early training.

For example, a common mistake made particularly by Psychology undergraduates when writing laboratory reports is to claim that

"...not enough subjects were run in the study.....and that the study was limited because of this......and future studies should repeat the study with more participants".

This is nearly always one of the most unconvincing arguments students ever make. In contrast to their claim of low sample size, quite often we find that the statistical power was more than sufficient to make some claims. In addition, we often find that many of the results were indeed highly significant. So if there are clear and significant results (and not borderline results), it is a good general rule that low numbers of participants should not be a major concern. Why? Because it does not explain the significant effects one has measured. Obviously low numbers may be a concern with some null effects and effects that are borderline, but if this is not the case students should not be afraid of getting down to the job of interpreting their results. Using the *"we need more subjects for the experiment"* argument is generally seen as a "cop-out" by tutors and is certainly not representative of an elegant or well thought out argument against a study with good significant results. Students know they need to be critical – but don't yet, at this stage, know how to be critical. They are often fearful of putting forward an argument in case their account is shown to be wrong. So the typical strategy is often to air on the side of caution and play it safe with standard and relatively unconvincing arguments of “low sample size”.

A similar point is recruiting a source of random error to explain a systematic effect. Although random error (or ‘noise’) should be reduced as much as possible – it can never be totally eliminated. However, although random error is always present it is often difficult to see why or how it has any implications for any significant and systematic effects that might be reported. Consider a student running a computer-based experiment for his / her practical class. Let us also assume they measure a clear systematic effect in one condition, that is not present in a control condition and this difference is significant. Quite often students fall into the trap of writing their discussions with lots of irrelevant statements like

“the laboratory was noisy and maybe some people got distracted……the experiment was not run at the same time of day and so levels of awareness may have varied……etc”

The problem is these effects are random and as long as control conditions were run at the same time and under the same conditions – none of these comments can explain why a systematic effect occurred. Why? Because all these factors would also be present and impact on performance in the baseline and control conditions. In other words the error is random and impacts across all conditions equally (as random error and noise) and so cannot explain why we only have an effect in one condition. Of course, other forms of systematic error may explain the results – but the point is to make sure any explanation or counter-explanation provided can actually explain the pattern of findings measured.

Critical thinking should help the student realise why the example arguments above are weak and unconvincing. In summary it is important that ones arguments and critiques are actually pertinent to the original study, findings, and argument being made.

Finally, it is important that the critical thinker consider the facts without presupposing their content or how they are ordered. They must remain open-minded and must always be prepared to assess new information. However, one should not be so open-minded as to accept any claim that comes their way and thus descend into gullibility. The critical thinker should be cautiously sceptical of the evidence and arguments being made. In addition, the level of scepticism should be healthy, and not be to the extent that the individual becomes inherently dogmatic. It must be expressed to a degree which protects the thinker from self-delusion and error.

The critical thinker must be prepared to fully consider views that are opposed to their own irrespective of how uncomfortable that might be. This must be done fairly and objectively in a useful and helpful manner. Furthermore, the critical thinker must be reflective and also always be prepared to be wrong! There is nothing unscientific with shifting one’s opinion if that shift is based on new evidence and facts gained from appropriate scientific methodologies, logic and reason. Indeed, this is the process of science itself.

The practice of critical thinking ultimately aims to ensure, as far as is possible, that one’s views and ideas are as clear as they can be, that they are rational, logical, supported by evidence and can be justified. It is a method to ensure that one has reduced, as much as is possible, the potential for the individual to delude themselves with information that is fallacious and arguments that are logically unsound.

Part II: Principles of science and scientific reasoning

Critical thinking and the scientific method are closely related. It is perhaps useful for the present discussion here to outline just some of the major principles of scientific reasoning which are also pertinent for critical thinking. Part II covers just a few central aspects of scientific reasoning that any critical thinker should become familiar with.

On the nature of facts in science

A fact is not necessarily an absolute entity which cannot be questioned (they are not infallible). Indeed, many facts are revised, changed or abandoned as science progresses. However, as Carroll (2005) puts it, the things science currently holds as facts are those things which are confirmed to such a high degree it would seem somewhat perverse to refuse to endorse them. Although scientific facts are based on data – data and facts are not the same thing. Facts are data interpreted through theory. Science is not just concerned with the proof of facts but also the organisation of them into coherent knowledge (the structure and order of facts and knowledge within a global model).

On the nature of scientific theories

A scientific theory is an explanation or "version" for a particularly puzzling aspect of the world. Particularly explicit and well specified theories are sometimes also referred to as theoretical 'models'. Like the facts they draw upon, theories are not absolutes and are not infallible. The aim of a theory is to suggest the best way to understand the object of study at that time and based on the evidence currently available. So a scientific theory tries to suggest one way to understand the phenomena being studied. Theories vary in scope in terms of whether they offer only partial or more complete explanations of whatever is being studied. A fundamental aspect of science is that any theory should always be regarded as *provisional.* 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, 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 a religion or pseudoscience. Under these latter circumstances we are told that knowledge is final, cannot be questioned, and must be accepted as the word of some Devine entity. These beliefs require only that the individual accept them in an unquestioned manner. However, the crucial difference is that facts and evidence are those things which do not disappear if we choose to stop believing them. It is somewhat ironic that these very areas of pseudoscience often claim that it is science which is "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.

Principles of scientific reasoning: Falsifiability & Falsification

One of the fundamental principals in science is that of falsifiability. 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. As a rule, this process of falsification assures 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, falsification makes the explicit commitment that the evidence must 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. Hence, such statements are meaningless.

Let's think about this for a moment. If a claim cannot be tested in any meaningful way it cannot be falsified. If the claim cannot be falsified it is also the case that it cannot be confirmed.

Importantly however, this does not mean that the claim being made is in anyway actually true! When an argument cannot be tested and falsified it is untenable to claim it to be factual or true. Remember, in science every current and provisional 'true' claim can be falsified (that is to say we can think of evidence that, if it occurred, would show the claim to be false). Some of the strongest and most influential claims are those which have received repeated attempts at falsification.

The principle of falsification / falsifiability is often violated by pseudoscience and belief–systems, all of which claim certain truths about the world. These areas either do not fully understand the principle or even actively avoid it. This invariably leads to many claims and arguments that are based on false premises, which are logically unsound, and are ultimately meaningless when examined in detail.

Indeed there are instances where the very absence of evidence (because the claim cannot be tested and falsified) is taken as evidence and support for the claim! This is based on a fallacy of reasoning that the absence of disconfirming evidence carries the same degree of evidential weight as the presence of confirming evidence. It does not. The failure to disprove a claim is not, by default, evidence in support of it. If the absence of disconfirming evidence were to be taken as proof for a claim, then we could show absolutely anything to be true – even when it is totally false.

For example, a common argument from Parapsychologists is that the paranormal dimension or world does exist but that it interacts with our physical world in a manner that does not obey the known laws of physics. As a consequence of such an exotic mechanism – the paranormal is "so special" it cannot be measured by mundane science. This argument has been applied to the mind being separate from the brain, extra-sensory perception, the survival of bodily death, and the existence of apparitions. It is a generic idea which is an excellent example of an argument that violates the falsifiability principle.

Remember, the absence of evidence for a claim (because it cannot be tested in any way) does not provide any support for it. If we have no evidence either way (negative or positive) because the claim cannot be tested, it is no more likely to be true as it is to be completely false.

The absence of evidence means nothing either way and cannot be recruited by either side of the debate as support for any claim. It could be that there is no evidence because the idea is simply false and untrue. It is crucial for any argument to have confirming evidence to support it. The critical thinker might want to take an issue like this and turn an untestable idea into a testable one by examining the premises and logic, generating clear predictions, and testing them via an appropriate methodology.

Principles of scientific reasoning: The role of Premise & Logic

Any argument that is offered in support of any particular claim must be logically sound. The soundness of an argument is based on the premises made and the logical connection between them. As Lett (1990) states;

"An argument is said to be 'valid' if its conclusion follows unavoidably from its premises; it is 'sound' if it is valid and all the premises are true. The rule of logic thus governs the validity of inference." (Lett, 1990; pp3).

If an argument is invalid, then it follows that it must be unsound. However, importantly not all valid arguments are actually sound. Consider the following example: "all humans have hair on their head; Dave is a human; therefore Dave has hair". The argument, while being valid is actually logically unsound. It is unsound because the first premise is totally false – all humans do not have hair on their head – many people can be bald and these instances show the argument to be false. The point is an argument can still seem to 'flow' and make a degree of 'sense' – but the premises it recruits may well be false. So, when an argument is considered valid – all we really know (at this stage) is that if the premises are true, then it follows, so is the conclusion. However, validity alone does not tell us anything about whether the premises are true or not. Other fallacious arguments can involve sound premises, but the logical connection between them is false. Understanding arguments in this way will improve our ability to think clearly and critically about claims and arguments asking us to accept them as being true.

Interestingly, the example above also illustrates the crucial importance of the *"counterexample"* in scientific reasoning and argumentation. Any argument can be shown to be invalid by recognising the existence of relevant "counterexamples". If it is at all possible to think of an example where the conclusion would not necessarily follow from the premises (even if they are true), then the argument can be said to be invalid – and as such, unsound. Therefore, a single instance where the conclusion does not automatically follow from the premises can provide an effective counterexample.

The example of the "bald man" given above is referred to as a syllogism within the field of logic. It is not necessary to go into any real depth on the nature of syllogisms here. However, they do show a useful and important tool in evaluating arguments. Syllogisms illustrate how any complex argument can be broken down or decomposed into a series of premises or statements which have a particular connection between them, leading to a necessary conclusion. It is always a good idea when dealing with any particularly complex argument to break it down and summarise it by a series of basic statements and premises. This also makes it easier to evaluate the complex information in many arguments and deal with them separately.

If a complex argument makes a number of assumptions and depends on a series of premises, it is worth breaking the argument down and considering each in turn. It may well be the case that the argument depends on one particular crucial premise, which relative to all of the others, is actually unfounded. This would reveal a crucial flaw in the soundness of the argument, and as a consequence, the whole argument can be questioned.

Principles of scientific reasoning: Avoiding circular reasoning

An argument must not stand on its conclusion – but its premise, facts, evidence and reason. A common mistake often made by students is the fallacy of the circular argument. A circular argument is one where a big assumption (possibly even a conclusion) is used to set up an argument which then in turn supports the initial assumption. Basically, the fallacy here is where one assumes to be true, that which one is actually trying to prove in the first place. Circular reasoning is often also referred to as "begging the question" – where the conclusion begs the question which is supposed to support the conclusion (hence the reasoning is circular).

Many arguments from parapsychology start with a conclusion like "let us assume the paranormal exists". From this it might be argued that apparitions could be real, which in turn supports the original contention that the paranormal exists. We thus go full circle. Of course the problem here is that many use conclusions as premises, which facilitates the circularity.

Principles of scientific reasoning: The importance of Replicability

When considering multiple sources of evidence we need to make sure, as much as possible, that the evidence is not due to chance, coincidence, or error. Findings which have been independently replicated across studies and researchers should be given more weight in an argument than those which have not. We can be more confident about them. The rule of replicability is a very effective way of controlling for any possible effects of experimenter bias, error and even conscious fraud. Therefore, when evaluating evidence a general rule might be to lend more weight to findings that have received more independent empirical support. However, it would be unfair to criticise recent claims for not having much support relative to a theory that was proposed say, 25 years ago. The lack of support for the new theory may simply be due to the fact that science has simply not yet had the chance to carry out further studies. It does not necessarily mean that the arguments are incorrect. It is also important to concentrate not just on the quantity of evidence – but also its quality as well.

Principles of scientific reasoning: The Comprehensiveness of evidence

It is crucial that any argument or theory does not just consider the evidence which supports it and ignore the evidence that contradicts it. Consider the following anecdotal example: many people report a common perception of thinking about someone, when the phone then rings and the caller is the person we were thinking of. Is this evidence for a psychic ability between these people? The answer is no. Although many of us 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 also known as the confirmation bias (where we are biased to only notice observations that confirm our assumptions). By acknowledging this as a potential flaw in our reasoning, the tools of critical thinking prevent us from making these errors in our own arguments and spot them in the arguments of others.

Although it is important to consider many forms of evidence, it is impossible to consider all forms of information claiming to be evidence. The task here is to isolate what forms of evidence are most relevant and of high quality. The best way to think about this is to consider the most probable alternative accounts as opposed to every possible fanciful idea.

Part III: Critical thinking & argumentation

In contrast to popular opinion, constructing an argument against an idea or claim does not entail attacking anyone. In the climate of scientific debate, an argument is not a personal quarrel or a fight. A scientific argument (based on the process of critical thinking) is the construction of a reasoned case for a particular conclusion, over other potential conclusions, based on the available evidence. So an argument is really putting a clear case forward based on sound reasoning, logic and evidence.

To this end, critical thinking can help us in two crucial ways. Firstly, it can help us construct our own arguments that are based on well-founded premises, based in logic and reason, are rational, and provide useful understandings. Secondly it can help us to evaluate and assess the arguments put forward from other sources in a fair, objective, and helpful manner. The principles of critical thinking are actually the same under both circumstances – they are just either directed towards our own arguments we are trying to construct (in an attempt to self-regulate that our own arguments are sound) or towards the other sources.

One of the biggest failings that many undergraduate and postgraduate student essays show is a failure to construct an effective argument. Although some of these factors may be due to limitations in writing style and ability, for the most part it can be put down to the lack of any critical thinking being used to construct a well reasoned argument.

Quite often students fall into the trap of putting forward arguments they have read in basic textbooks – which are nearly always over-simplistic, unconvincing and unlikely to answer any university course question. In other words – students often 'borrow' an argument they have read rather than provide an opinion of it, or even generate their own through objective free-thinking.

Students often make the mistake of thinking that a good argument is one where the conclusion is a somewhat neutral one, neither taking one side nor the other conclusively. When writing essays and constructing arguments they often fall into the trap of discussing evidence for and against an issue, concluding little more than, *"further evidence is needed before we can be sure of anything"* . However, the outcome of critical thinking is not to arrive at an "on the fence" opinion (as this is functionally equivalent to no conclusion at all), but to carve out a position that sees the evidence in a particular manner. The evidence considered should be balanced but for a conclusion to be truly useful it will need to clearly suggest one interpretation over the competing ones. A good balanced argument is not a theoretically neutral one!

Characterising an argument

Before we can critically evaluate an argument we have to characterise it correctly. By characterising an argument we are defining what sort of argument is being made, at what level, and in what manner. The quicker we can characterise an argument the easier it is to evaluate it clearly and fairly. Stripped to their bear bones most arguments will consist of the same elements. For example, arguments generally consist of a number of premises, reason statements and conclusion statements.

Imagine we had two scientists making two separate claims about the relevance of computational modelling in constructing brain-based theories of cognitive processing. The first scientist makes the following claim: (i) that computer simulations are literal models of brain functions – in other words, they do what they do exactly as a brain does it. By this account computer simulations are exact models of brain function. The second scientist makes the claim that (ii) computer simulations are not literal models of brain functions, but they are somewhat 'brain-like' in their operation. Therefore although they are useful for constructing and testing psychological models they may well not be literal incarnations of real cognitive systems. By this account simulations and brains are similar – but not necessarily the same. The first claim is more extreme and is a completely different type of argument relative to the second mellower one. The important point is, although both are claims about the role of computational modelling the same criticisms do not apply to both claims. It would be inappropriate to counter the second claim with an argument saying that *"but the brain is not identical to a computer, the many differences may outweigh the many similarities"*. Note that the second claim never said the brain was 'identical' to a computer simulation – just that the metaphor and framework may have merit for psychological theory. So the counter-argument is invalid as it attacks the claim for something it never stated in the first place. This is a failing of characterisation – the argument has not been characterised properly by the counter-argument. Being able to characterise an argument correctly is extremely important. Sometimes, mistakes in characterising an argument are simple mistakes on our part and others may point this out to us. Maybe we misread or misunderstood the original claim (for whatever reason). However, it is also common in some areas to mischaracterise an argument on purpose.

If we fail to characterise an argument appropriately, all that follows may be a completely meaningless exercise. A common mistake made in debate is a concept known as "the straw man" debate. Sometimes this is a premeditated debate tactic and sometimes it is accidental. The straw-man debate refers to a case where one generates an argument against a certain form of existing argument – that in fact never existed in that way in the first place (similar to that discussed above). Thus, you build a "straw man" because it is easy to knock down. The arguer actually knocks down a fictitious argument to boost the case they are making (politicians are particularly prone to constructing straw-man debates). In reality for such arguments to work, they require and depend on the misrepresentation of, or the inappropriate characterisation of, the original arguments being addressed. So straw-man debates are conceptually proximal to real debates, indeed they must be, but they do a great disservice to the real argument. They misdirect the attention of the individual.

Consider this final example of a straw man debate from the field of Parapsychology. In the 1980s / 1990s - scientists suggested the 'dying-brain hypothesis' (see Blackmore, 1993) as an explanation for Near-Death-Experiences (NDEs). The dying brain hypothesis states that as the brain is dying it enters a state of extreme neural disinhibition (i.e., over-excitation) which underlies striking and vivid hallucinatory imagery. Under some of the more extreme circumstances this process of disinhibition is likely to be initiated by anoxia (oxygen starvation in the brain due to cardiac insufficiency). In response to this some Parapsychologists argued against the dying brain hypothesis for NDEs on the grounds that individuals can have an NDE without there being any anoxia present. The counter claim was that, as anoxia was the key component to the hallucinatory theories, experiences that occurred without heart-arrest and thus anoxia, show that the anoxia theory is false. If NDEs can occur in the absence of anoxia, the anoxia account must be false and thus cannot explain NDEs. The conclusion from this is that, by default, it must be paranormal! Sound reasonable? Well, hang on.

A closer examination of the arguments is revealing. Importantly, the dying-brain hypothesis NEVER said all NDEs are solely due to anoxia. What it DID say was that the hallucinatory imagery experienced in NDEs is a result of excessive neural disinhibition. When close to death, the brain will start to enter seizure states and a process of neural-disinhibition will be initiated. However, anything can start this process - even confusion, sensory deprivation, and disorientation. In other words it is disinhibition that is crucial, not the presence / absence of anoxia per-se. Disinhibition can occur for a host of reasons, many of which are totally independent of anoxia. So NDEs which occur in the absence of anoxia are not evidence against the original account of the dying brain hypothesis at all. Indeed, the original theory makes clear provision for such instances.

The argument that non-anoxic NDEs are evidence against the dying-brain hypothesis is a good example of a 'straw man' debate. It is a counter-argument against an original argument that was never actually proposed in the first place. It is a severe error in the correct characterisation of the initial argument.

Evaluating arguments

You cannot really evaluate an argument critically until you understand it properly. This is something students often find difficult. Having characterised an argument we need to decide whether we know enough about the argument being made. If not, then the conscientious critical thinker should seek out the relevant information to help understand the argument more fully (ignorance never leads to understanding). Assuming we understand the argument being made we are now in a position to examine it more closely.

A more detailed step-by-step guide to evaluating arguments is given at the end of this paper. Here we will give a very brief overview of the generic process. An initial question we should ask is; what is the claim that we are being asked to accept as true? This should be summarised into a simple statement or a small number of statements. Once done, we should identify the premises and assess whether the premises, on which the argument draws upon and depends, are actually supported and true (valid). The best premises are those which do not buy into lots of others in order for them to appear sound. If a premise requires a great deal of qualification, or makes many other co-assumptions one should view it with some scepticism and investigate further. A scientific premise should be as clear and unambiguous as is possible. It should not be sweeping and should not be a grand conclusion in itself. Having examined the premises the next step would be to investigate the underlying logic and links between the premises. Does the logic flow between the premises (are they correctly ordered and does the conclusion necessarily follow from the premises)? The reasoning should be examined for validity and soundness and the nature, form and quality of the evidence from multiple sources should also be considered (see the guide at the end of this paper for more detail).

There is one trap that must be avoided when evaluating arguments worth highlighting here. When faced with two extreme positions it can seem tempting to take the 'middle ground' between these extremes. A good example of where this seems to work well is the nature / nurture debate within psychology. The current consensus seems to be that both factors are important and both make varying contributions to the object of study. However, on occasion this might not be the best way forward. Taking the middle ground in a debate means that we acknowledge both extremes are true in the first place. It could well be that both extremes are in fact totally false – and so there is no middle ground to be taken at all! If account A is false and / or account B is false, it undermines the need and rationale for taking a moderate view between false extremes. It is important that the critical thinker considers the fact that many arguments and claims could well be totally false as opposed to partially correct.

For example, consider Newton's observation of objects falling to the ground. Initially we could generate three ad-hoc hypotheses. We could view the effect as being due to the objects being pulled to the ground. Alternatively we could view the effect as being due to the sky pushing down. A mid-way point between these extremes is that both processes (earth pulling & sky pushing) could be playing a part. However, clearly this is false – and it is false here because one of the extreme positions (the sky pushing) is false. Thus, the perception of a theoretical middle ground is an illusion and can lead to error.

Omissions from arguments

It might sound an odd thing to say, but it is also important to assess arguments on the basis of the evidence they omit as much as that which they include. However, it is important to remain focused on the correct characterisation of the argument to do this fairly and effectively. It would not be a particularly helpful approach to claim that a particular argument has omitted some findings, when in fact those findings are actually irrelevant to the nature of the original argument being made. This is a common mistake. However, assuming one notices some relevant omissions from an argument, it would certainly be worthwhile to assess these omissions and their implications for the arguments being made.

Strong and persuasive arguments are the ones that recruit the most comprehensive range of evidence currently available. A good example is the theory of Evolution. It is very important that any theory tries to accommodate not only the evidence that supports it, but also findings which go against it (see the section on comprehensiveness). There may be good reasons why some studies have provided mixed results, and contrary evidence exists. These reasons need to be identified and examined.

What is necessary and sufficient for the arguments being made

It is important that the evidence recruited to support an argument or theory can actually establish the truth of that argument. For example, anecdotal observations are not sufficient on their own to establish any theory for the observation. The quality of evidence is insufficient to show the claims for it to be true. Ideally an explicit argument will outline the conditions that are both necessary and sufficient for a claim to be true.

For example, if A is a necessary condition for B to occur, it is impossible to have B without also having A. To put it another way, the absence of condition A assures the absence of B. To establish that A is not a necessary condition for B, we need to find a situation where B is present but A is not. A good and common example is that having four sides is a necessary condition for a shape to be a square. A square cannot be a square unless it has four sides. So this is a necessary pre-requisite. However, having four sides, though necessary, is not sufficient on its own for any shape to actually be a square. Based purely on the single fact of having four sides it could also be a rectangle or a rhombus (for example). Some claims may require a number of necessary statements in order for them to be true.

In terms of sufficiency – we may say that A is a sufficient condition on its own for the presence of B. What this means is that the mere presence of A absolutely guarantees the presence of B. Therefore, it is impossible to actually have A without also having B. Related back to our above examples, a shape being a square is sufficient for it having four sides. Being a moving stimulus is both necessary and sufficient for not being a static one, and so on.

As with necessary conditions, some arguments can have more than one claim of sufficiency. When considering an argument or claim there may be a number of possible relationships between necessary and sufficient statements. For example, (i) A is a necessary, but not on its own, sufficient case for B to occur; (ii) A is sufficient but not necessary for B to occur; (iii) A is both necessary and sufficient for B to occur, and finally, (iv) A is neither a necessary nor sufficient case for B to occur. These conditions can help the individual understand how concepts are related to each other within an argument being made.

On the role of speculation

The emphasis science places on data, facts and evidence does not mean there is no role for speculation in theory. There is. Indeed, many insights have been gained from a premise based in initial speculation. However, such speculation differs in a number of ways from the somewhat random and unwarranted speculation of the pseudoscientist and poor thinker.

Firstly, scientific speculation is usually characterised appropriately as a speculation in the first place. This is important for viewing how the speculation compares with other ideas and theories in the area of study. Secondly, the speculation often draws heavily on the correct characterisation of existing knowledge and theories. Thirdly, successful speculations often keep close theoretical proximity to the available information (a minor extension).[2] Finally, successful speculations are usually followed soon after by some empirical finding that speaks to the issue one way or the other.

In contrast, pseudoscientists often speculate wildly and often speculation is based on unfounded premises. So their version of speculation (based in the argument that scientists speculate as well) is simply a different process altogether.

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[2] Of course this is not always the case. Sometimes new speculations can be quite radical. However, when they do differ markedly from current understandings there should always be a sound reasoned case justifying their necessity.

Students often fail to either speculative at all, or speculate appropriately when they do. The practice of critical thinking should aid and guide the speculative process to an appropriate level and scope as to further aid understanding and insight.

Conclusion

The present paper has provided a basic introductory guide to critical thinking, logic and reason. To illustrate the need, role, and function of critical thinking, real world examples and examples from pseudoscience / parapsychology have been used. These areas provide fertile grounds for poor thinking, poor logic and the absence of reason. The paper has made a case for the need for critical thinking, has outlined what its major components are, and shown how to practise it in a legitimate and appropriate manner. By learning and developing the skills outlined here, the reader will be better equipped at generating their own arguments and evaluating those of others. For the student, clear thinking leads to clear writing and this should help improve their performance across numerous areas of study. Of course, critical thinking and reasoning does not guarantee that your views will be true, but you do greatly increase your odds in favour of truth relative to self-delusion and error.

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Blackmore, S. J., (1993) Dying to live: science and the near-death experience. London. Grafton.
Carroll, R. T., (2005) Becoming a critical thinker. A guide for the new millennium (2nd Ed). Boston. Pearson Custom Publishing.
Lett, J (1990) A field guide to critical thinking. Skeptical Inquirer (14), 2, 1- 9.

Recommended Further reading:

Browne, M. N., & Keeley, S. M. (2003) Asking the right questions. A guide to critical thinking (7th Edition), New Jersey. Pearson Prentice Hall.
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Some basic tips on how to evaluate arguments

(i) Characterise the argument being made appropriately (the type of argument, level of argument, nature and form of argument, scope of argument). Make sure all that follows is in line with this characterisation.

(ii) Ask yourself clearly – what am I being asked to accept (what are the claims / argument being made)?

(iii) Identify the premise(s) on which the argument is based (what assumptions do these make? Are these valid)?

(iv) Make sure you fully understand the argument in the manner in which it is being proposed. If not, seek out further information until your grasp is sufficient to evaluate the claim.

(v) Identify both the claimed and the unclaimed logically links between the premises (are these sound and supported? Do these make sense and logically follow)? Ask yourself, what are the logical consequences of the premises and are these fulfilled in the argument being presented?

(vi) Identify and examine any predictions that follow from the argument (both the predictions made explicit within the argument and others you have independently spotted) - are these supported?

(vii) Identify any ambiguity in the argument that demonstrates its limitations.

(viii) Identify necessary and sufficient conditions and links between claims and statements within the argument.

(ix) Think about the methods used to generate the evidence - are these methods valid / reliable? Can they support the claim?

(x) Consider the nature, form and quality of the evidence. What is the evidence being recruited to support the argument? What is the evidence that goes against it? What is the quality of both sets of evidence? Are these sources of evidence equally reliable and trustworthy?

(xi) Has any evidence been omitted from the argument being made? If so, what are the implications for the argument?

(xii) What are the reasonable conclusions that can be drawn? Are these the conclusions that actually are drawn? If not, how do they differ?

(xiii) Examine the conclusion – is it in line with the type of claim / argument being made, is it in line with the nature & form of the methods and data (i.e., correlation does not establish causality).

(xiv) How complete is the argument?

(xv) Think of counter-examples – are there any and what do these tell us about the arguments being made (is the argument correct, incorrect or simply need refining and revising)?

(xvi) What evidence would be needed to invalidate the argument and / or support it further? What tests have been done that speak to this?