Darwin's Mind:
The evolutionary foundations of heuristics and biases

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Abstract:

The catalogue of biases that cognitive psychologists have built up over the last three decades seem to have stem from one of three roots – self-deception, heuristic simplification (including affect), and social interaction. This paper attempts to explore the evolutionary basis of each of these roots. The simple truth is that we aren't adapted to face the world as it is today. We evolved in a very different environment, and it is that ancestral evolutionary environment that governs the way in which we think and feel. We can learn to push our minds into alternative ways of thinking, but it isn't easy as we have to overcome the limits to learning posed by self-deception. In addition, we need to practice the reframing of data into more evolutionary familiar forms if we are to process it correctly.

Key words: heuristics, biases, rationality, evolutionary psychology

Introduction

Considering that cognitive skills are so important, we seem to spend remarkable little time thinking about how we think. Perhaps nowhere is more obvious that in the industry in which I work – the financial arena.

Take analysts, these individuals are (supposedly) highly skilled professionals deeply schooled in the industries they follow. The training courses offered by HR departments are more likely to focus on presentation and communication skills, or valuation techniques than on the right way to think.

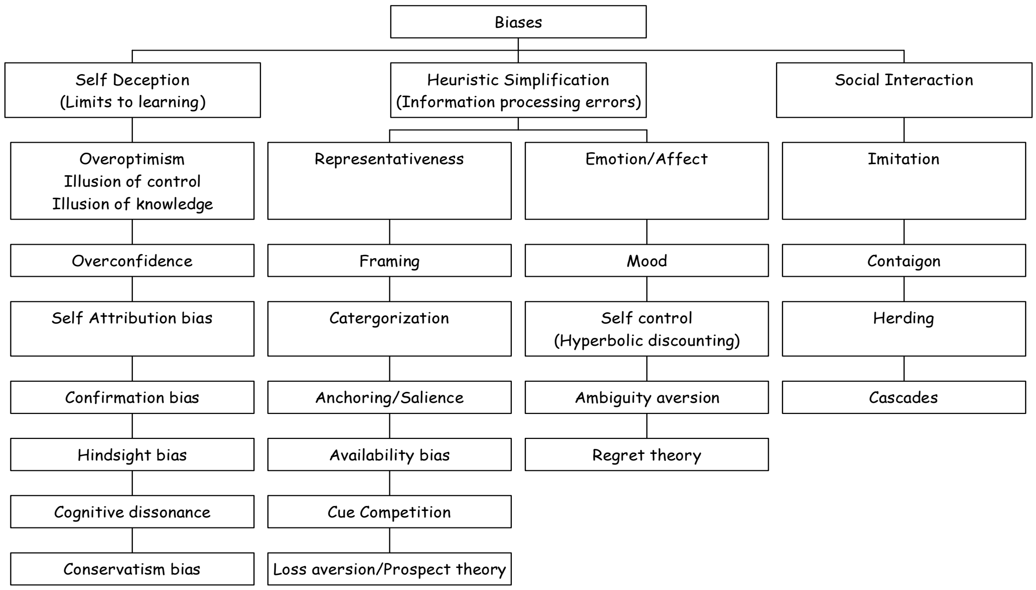
Even at school few children are ever presented with material on how we should approach thinking. Indeed many people take umbrage when the teaching of cognitive skills is even mentioned. After all surely they can already think, such an affront to self-image is not generally well received (an example of one of the self deception biases we will address below).

Despite this reaction, psychologists have spent many years cataloguing the inaccuracies of our thought processes. This process was inspired by the work of Kahneman and Tversky (see Kahneman and Tversky (1982) as the classic reference) and is now the basis of behavioural economics. This paper seeks to explore the neurological and evolutionary roots of these biases.

A taxonomy of bias

Hirschleifer (2001) suggests that most of the mistakes we make can be traced to four common causes: - self-deception, heuristic simplification, emotion/affect, and social interaction. I believe that this taxonomy can be simplified one stage further. I will argue below that emotion is integral to the cognitive function, to talk of thinking without acknowledging feeling becomes impossible under this view. The table below tries to classify some of the major biases grouped along the lines suggested by my approach.

A taxonomy of biases



The challenge in this paper is to explore the three root causes of heuristics and biases using the insights from both evolutionary psychology and neurobiology. Before embarking on a detailed discussion some background on these two approaches may be in order.

Evolutionary psychology

Evolutionary psychology takes the tools and techniques of evolutionary biology such as fitness and adaptation and uses them to understand why our mental processes are the way they are.

The ultimate evolutionary aim for any gene is to ensure its existence in the next generation. Adaptations are solutions to reproductive problems. For instance, muscles are an adaptation, and their function is to apply force to various parts of the body. In general, all members of a species of the same sex and developmental stage share the same functional organisation (i.e., have the same adaptations). All humans have bones, muscles, hearts, eyes, etc. Adaptations should improve fitness. Fitness is our ability to pass on our genes, which in the Darwinian scheme of things is the ultimate motivation.

While some problem solving abilities (functions) of the nervous system are obvious (e.g., vision), many are not; the goal of evolutionary psychology is to identify all the functions of the cognitive system

Evolutionary psychology seeks to explore the ways in which our minds have been formed by the process of evolution. Simply put Homo sapiens sapiens (you and I) have been around for some 120,000 years (itself a mere blink of evolutions eyes). However, we have lived in an agricultural society for a mere 30,000 years and an industrial society for a paltry 300 or so years. Our minds are suited for survival in the evolutionary ancestral environment (effectively the African Savannah).

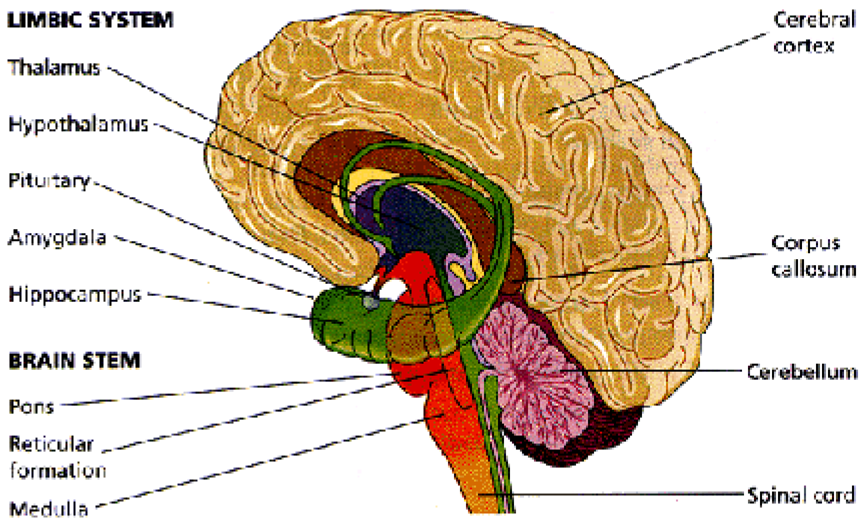
Evolutionary psychologists ask us to understand that "Our brains are shaped for fitness not for truth" to borrow Steve Pinker's turn of phrase. That is to say that our minds are best suited to a past environment where the problems we faced concerned survival rather than the kinds of problem that we face today.

Perhaps the key mistake that evolutionary psychologists must seek to guard against is pan-adaptism, or the tendency to make up "Just so" stories to explain every facet of human nature.

Neuropsychology

Neuropsychology attempts to understand how the physical construct of the brain is related to the cognitive and emotional processes. Part of this work involves mapping the mind, and periodically we will refer to some of the findings from this field.

The diagram below outlines some of the main features of the brain. In particular, I draw your attention to the neocortex, and the limbic system. These two areas will be of prime importance when we are discussing the neuropsychology of dual processing systems below.



Self deception

The first major category of heuristics and bias that I wish to examine comes under the collective heading of self deception (limits to learning). These biases are the ones that lead us to believe that we are better drivers than average. Ask a room full of people how many of them are above average lovers, and the normal response is everyone! Ask a class of students who will finish in the top half of the class and around 80% of them believe they will. I've asked many audiences of fund managers over the years if they think they are better at their jobs than average, and far far more than half believe they occupy such a niche. Effectively we all like to believe that we inhabit Garrison Keillor's Lake Woebegone, where the "women are strong, the men are good looking, and all the children above average".

I have labelled this category as limits to learning as well as self deception. Economists frequently tend to labour under the assumption that learning will be an unbiased process. However, psychologists generally question this belief. For instance, a trait known as self attribution bias presents a real challenge to learning. Self attribution bias refers to situations whereby good outcomes are attributed to skill, whilst bad outcomes are attributed to bad luck. If mistakes are categorised as bad luck, what hope have we for learning from them?

Michael Gazzaniga, a neuroscientist, has shown that we lie to ourselves. The brain literally weaves a tissue of lies to justify its behaviour. Split brain patients are individuals who have had their cerebral hemispheres surgically disconnected as a treatment for epilepsy (the corpus callosum is severed). Each half of the brain still functions, but there is no longer any communication between the two.

Most functions of the sensory inputs to the brain are crossed wired, such that, for instance, the left half of the field of vision is received and processed by the right hand side of the brain. Gazzaniga (1972) found that showing split brain patients images to their left eye, and hence their right hemisphere had some rather bizarre results. The patients generally did as instructed on the card, for example “walk” or “laugh”.

However, when the patient was asked why they walked out of the room, or started laughing, the left hemisphere starts to make up motives (remembering that the information was only seen by the right hemisphere). For instance, one of the patients who was asked to walk, when asked why he walked, stated he wanted to get a Coke. When asked why he was laughing the patient replied “You guys come here and test us every month. What a way to make a living!”. It should be noted that only the “thinking link” between the patient’s brain is cut, the emotional link (stemming from anterior commissure- a far older and deeper hidden part of brain) still functions at a base level.

Perhaps the most bizarre of Gazzaniga’s findings concerned a young man known as P.S. Unlike most people P.S had language skills in both hemispheres of his brain. When asked verbally what he wanted to do post graduation, P.S replied that he wanted to be a draftsman. However, when he was asked to wanted to do when he graduated but the last word was flashed to his left eye (and hence P.S’ right hemisphere), P.S. spelt out Automobile racer using a scrabble set and his left hand (remember the bodies functions are cross wired).

Nor is it just split brain patients who make up excuses to justify/rationalise behaviour. Nisbett and Wilson (1977) laid out many pairs of stockings, and asked ladies to select which pair they liked the most. When the women were questioned as to the reasons for their selection, they volunteered all sorts of wonderful excuses about texture and sheerness. However, all the pairs of stockings were actually identical!

How on earth could self-deception actually prove to be an evolutionary winner? Two avenues can help explain our natural tendency towards self deception. Firstly, within communal living, the ability to spot cheaters will be a useful function.

Homo sapiens sapiens seem to have generally lived in small groups throughout their history. Indeed, even our evolutionary ancestors such as Australopithecus seem to have lived in groups. The logic for group living is obvious within the evolutionary ancestral environment.

The most immediate benefit of communal living is the safety in numbers concept, indeed such behaviour is visible within chimpanzees today. Secondly, humans were effectively hunter/gather societies. Food was shared out to smooth fluctuations in the food cycle. Freeloaders for protection or food sharing would be a burden upon the group, hence the ability to spot cheaters becomes a useful skill.

To demonstrate our skills in cheater spotting Cosmides and Tooby suggested looking at Wason selection tests. They suggested two forms of the test.

First, look at the four cards below, each is labelled with a letter on one side , and a number on the other. If I tell you that if a card has a E on one side is must have a 4 on the other side, which cards do you need to turn over to see if I am telling the truth?

E	4	K	7

Before I give the answer now consider the following. You have been employed at a night-club as a bar manager. However, the club is keen not to allow underage drinking. If someone is under 18 years old they must not drink alcohol. Now in the problem below each card is a customer: it says the customer's age on one side, and what he/she is drinking on the other side. Now which cards do you need to turn over to check there is no illegal underage drinking going on in the club?

Drinking Beer	25 years old	Drinking Coke	17 years old

In both cases, the correct answer is the first and last cards only. In the latter problem this should be obvious – you are looking only at those people drinking alcohol, and only those people under the legal age for drinking. In the former problem, these are the only two cards that can prove I was lying (if you thought E and 4 then you are suffering from confirmation bias, looking for information that agrees with you, another limit to learning!)

Cosmides and Tooby carried out numerous control tests to ensure that the framing of the cheater selection problem was at the heart of their finding and each test confirmed that it was indeed. Effectively, the human race is a group of walking lie detector machines! However, note the importance of framing. We find it incredibly hard to see through the way in which information is presented to us. The brain is effectively modular, if a problem is presented in a familiar fashion we can solve it, but in another guise we fall flat on our faces. Hence framing could become the most important bias of all (more on this below).

Now how does this all relate to self deception? Well, Trivers (1985, 2000) argues that in a world of walking lie detectors one of the easiest ways of fooling them is to fool yourself. In order to avoid detection we effectively lie to ourselves. If we don't consciously know that we are lying then we are likely to be able to fool those who are seeking to assess such motivations.

For example, the lover saying with all his heart, "I love you more than anyone else in the world. I will be faithful to you forever". This message is likely to be all the more convincing if the lover can conveniently forget that he said exactly the same thing to someone else a year earlier! Such self deception is likely to lead to success in mating, and hence the further of genes. In Darwinian terms, self deception is fitness enhancing.

Of course, knowing the truth could be useful to us, but it is contained in a walled off area of the brain, hidden from both the conscious part of the brain and other people.

A second evolutionary rational for self-deception comes from the work of Taylor and Brown (1988). They take issue with psychologists' usual belief that somehow a "well adjusted" person engages in accurate reality testing. The usual short hand definition of mental health is a well-adjusted person is one who sees what is actually there. Taylor and Brown go on to argue that "positive illusions – namely unrealistically positive self-evaluations, exaggerated perceptions of control or mastery, and unrealistic optimism" are adaptive for mental health and well-being.

Freedman (1978) finds that most people report being happy most of the time. Around 70-80% of respondents report themselves as moderately to very happy. Whereas most believe that others are only average in happiness, whilst fully 60% of people believe they are happier than most people!

Freedman goes on to link high self-esteem and high ratings of control as correlates of happiness.

Taylor and her various authors have found that certain groups (such as cancer patients, and AIDS suffers) may benefit from positive illusions, see Helgeson and Taylor (1993), Reed (1989) and Wood, Taylor and Lichtman, 1985). The belief that one is healthier or coping better than other similarly afflicted patients is associated with reduced distress.

In general, Taylor finds that a mild degree of self deception as it applies to self-evaluation and the such like, fits far better with psychologists working definition of mental health. Indeed, those who are classified as mildly depressed by psychologists seem to lack the positive illusions that dominate the rest of us. Taylor and Brown point out that these individuals tend to recall both the positive and negative self–relevant information with equal ease, show greater evenhandiness in their attributions of performance, and display high degree of congruence between self-evaluations and external evaluations. They conclude "In short, it appears to be not the well-adjusted individual but the individual who experiences subjective distress who is more likely to process self-relevant information in a relatively unbiased and balanced fashion." So in as much as "mental health" is an important fitness trait, self deception once again helps to be a Darwinian winner.

Of course, self-deception can not go unchecked. Triver and Newton (1982) show how a high degree of self-deception played a major role in a tragic aeroplane crash. Effectively the pilot of the doomed flight was massively over-confident and overoptimistic. The co-pilot was clearly highly nervous about the flight and the prevailing conditions (snow and ice). The pilot's self deception and evasion of reality proved tragically fatal to the passengers of the flight.

Conversations during taxiing prior to take off

Co-pilot	Pilot
Detailed description of snow on wings	Diminutive description of snow on wings
Calls attention to danger they face (too long since de-icing)	Deflects attention to ideal world (de-icing machine on the runway)
Asks for advice on take-off	Tells him to do what he wants

Source: Trivers (2000)

Wang (2001) also finds that modest self-deception may be a evolutionary stable strategy. Wang uses evolutionary game theory to study the population dynamics of a securities market. In his model, the growth rate of wealth accumulation drives the evolutionary process, and is endogenously determined. He finds that neither under-confident investors nor bearish sentiment can survive in the market. Massively over-confident or bullish investors are also incapable of long run survival. However, investors who are moderately overconfident can actually come to dominate the market!

Heuristic Simplification

First, I had better explain why I have moved emotion into the heuristic simplification. Since the times of the Greeks, humans have sought to separate reason and emotion. Plato opined that passions and feelings prevented us from thinking. In most religions, emotions are equated with sins. This approach has dominated the modern world as well. However, there is a growing group of scholars who argue that emotion and cognition are intimately related.

For a few moments, let us consider our minds without emotion. We would all be like Star Trek's Vulcans, unfeeling thinking machines. Indeed many of those working in the cognitive sciences tend to proxy our minds using such an approach.

But minds without emotions are not a good reflection of the human condition. A machine can be programmed to give a Grand Master a serious run at Chess (indeed just occasionally even beating the Grand Master). But it can't feel pride at the end of the game. It can't feel joy, happiness or the pain of losing. A machine can even be programmed to cheat at Chess, but does so without feeling guilt or remorse.

To understand how humans think we need to understand how emotions interact with the wider cognitive process. For instance, neurobiologists have shown that emotions are generally generated via interaction with the body. The unconscious generator of these emotions is the limbic system (in particular the amygdala). However, the neocortex also has a role to play in the conscious recognition of emotion.

Although neurobiologists hate to admit it, the brain's hemispheres do tend to look after different functions. Brains are highly advanced pieces of kit, we do them an injustice when we simplify them too much However, functional MRI scans do reveal that certain types of task seem to trigger hard wired responses from the brain.

The left hemisphere tends to be more analytical, more logical, more precise and is time sensitive and deals with abstract cognition. In contrast, the right hemisphere is more emotional, dreamier, it processes things in a holistic fashion, and deals more with sensory perception than abstract cognition.

This fits neatly with the ideas developed by psychologists that we have dual processing systems within our brains. For a review see Sloman (2002). The table below lays out the dual system proposed by Kahneman and Frederick (2002). Effectively, the left hemisphere is more akin to system two (the reflective process of cognition), whilst the right hemisphere is more closely correlated with system one (the intuitive approach). Both systems are likely to work in concert, with tasks passing between the two. Tasks may perhaps start out as the subject of system two reasoning, but migrate to be handled by system one, once they have developed a degree of familiarity.

System One **Intuitive**	**System Two** **Reflective**
Process Characteristics	
Automatic	Controlled
Effortless	Effortful
Associative	Deductive
Rapid, parallel	Slow, serial
Process opaque	Self aware
Skilled action	Rule application
Content on which processes act	
Affective	Neutral
Causal propensities	Statistics
Concrete, specific	Abstract
Prototypes	Sets

Joseph LeDoux, a neuroscientist and gifted writer lays out in clear detail in his book “The Emotional Brain”, that the emotion of fear has two neural pathways akin to system one and system two. The emotion of fear produces one of two reactions in extremis – flight or freeze. We either run from the threat or we freeze in the hope of eluding detection by the threat. This emotion seems to be served by two neural pathways. One fast and dirty, and notably evolutionarily much older. LeDoux refers to this as the low road. The other more reflective and logical, but much slower, referred to as the high road.

The danger is perceived (an emotional stimuli) and the sensory Thalamus processes the information. This information is then sent to two different centres. On the low road it passes to the Amygdala, part of the limbic system – one of the oldest parts of our brain. This all happens in the mental background and requires no conscious thought (system one). However, this is a pretty unsophisticated processing route, and frequently gives incorrect conclusions.

These conclusions are held in check in the other road. On the high road, the Sensory Thalamus sends the information of a threat to the Sensory Cortex which in a more conscious fashion assesses the possible threat, and then sends information to the Amygdala in order to motivate a response.

It is possible that phobias are caused by situations when the high road fails to kick in. For instance, my significant other suffers from a terrible phobia of snakes, to the extent that even watching one on television will send her running from the run, feeling queasy. Could this be a case of the low road triggering a response, but the high road failing to kick in and reveal that something on television can't possibly endanger you?

Let me give you an example where I might be able to prompt your two different systems to come to different conclusions. It is based on a 1950s game show, hosted by Monty Hall. Contestants were offered a choice of one of three doors. Behind two of the doors there was a goat, behind one of the doors there was a car. Upon selecting a door, the host of the show opens one of the two doors not selected, revealing a goat. After he has does this, he offers you the opportunity to switch your choice, what should you do?

The chances are your gut feeling is stick with the door you choose. When asked to explain this choice, you might say the doors are independent, so the opening of another door reveals nothing to you.

I have asked this question to some of the brightest people I know, and to a person I have yet to meet anyone who chooses to switch their choice. Indeed I have even seen professors of mathematics get heated under the collar arguing that the doors are independent and hence the revealing of a goat is irrelevant. However, the "correct" answer is that you should switch. Before you throw this paper away in disgust at my tomfoolery let me try to explain why it is that you should switch.

The probability that you will chose the correct door initially is 1/3, since there are three doors each of which has an equal chance of concealing the prize. The probability that the door Monty Hall chooses conceals the prize is 0, since he *never* chooses the door that contains the prize. Since the sum of the three probabilities is 1, the probability that the prize is behind the other door is 1 - (1/3 + 0), which equals 2/3. Therefore you will double the chance of winning by switching doors.

Now your reflective system of thinking can only see the correct answer, but remember at first you would have sworn that you would stick to your first choice of door. Your intuitive system was dominating.

Another example of the importance of emotions to cognition comes from the sorry tale of Phineas Gage. The strange story of Phineas Gage is beautifully documented in Antonio Damasio's insightful and powerful book, "Descartes' Error".

Phineas Gage was a 25 year old construction foreman working for a railroad company in New England in 1848. One of his many tasks was to push down the gunpowder into the blow-hole. However, before this is done the hole must be filled with sand on top of the gunpowder. On this fateful day, Gage was distracted and failed to notice that the hole had not been filled, with the disastrous consequence that he started to drive down the gunpowder directly.

His blows ignited the powder, and the three and a half foot rod he was using was blown through his head! Damasio writes "The iron enters Gage's left cheek, pierces the base of the skull, traverses the front of the brain, and exits at high speed through the top of his head". Gage is thrown to the floor, stunned and bloodied but amazingly still conscious.

Why am I telling you this gory and horrific tale of poor Mr Gage? It is the post trauma personality changes that are most interesting from our point of view. Gage went from being a capable, efficient and industrious employee to a drifter.

Carter (1998) cities John Harlow, Gage's doctor, describing the new Gage as "at times pertinaciously obstinate, yet capricious and vacillating, devising many plans of future operations which are no sooner arranged than they are abandoned." Neroulogically speaking, Gage had sustained large damage to the prefrontal cortex, specifically the ventromedial prefrontal region.

Antonio Damasio has spent large parts of his working life dealing with modern day equivalents of Phineas Gage. In "Descarte's Error", Damasio describes the life and times of Elliot, a 30 year old man. Prior to falling ill Elliot was successful and "well adjusted". However, he suffered a brain tumour, which was removed successfully. It had grown just above the midline, in the prefrontal cortex. Following the surgery, Elliot underwent a major personality change. He no longer seemed to be the Elliot known to his friends and family. Damasio describes a typical day for Elliot

> Consider the beginning of his day.: He needed prompting to get started in the morning and prepare for work. Once at work he was unable to manage his time properly; he could not be trusted with a schedule. When the job called for interrupting an activity and turning to another, he might persist nonetheless…Imagine a task involving reading and classifying documents of a given client. Elliot would read and fully understand the significance of the material, and he certainly knew how to sort the content. The problem was that he was likely, all of a sudden, to turn from the sorting task he had initiated to reading one of those papers carefully and intelligently, and spend the whole day doing so, Or he might spend a whole afternoon deliberating on which principle of categorization should be applied: Should it be date, size of document, pertinence to the case, or another?

Yet Elliot seemed to pass all the standard tests of memory, and personality that the psychologists could throw at him. Damasio did note that Elliot had the unnerving ability to discuss his condition without emotion. It later became clear to Damasio that Elliot could no longer feel emotion. Damasio became convinced that Elliot's emotionless state was intimately connected to his inability to make decisions.

Damasio has created the somatic marker hypothesis to help explain emotions' central role in the cognitive process. He describes the somatic marker as follows: before you even engage in any kind of cost/benefit analysis (reflective system two style thought), the brain runs some scenarios; when a bad outcome connected with a given response option comes to mind (even for the briefest moment), you experience an unpleasant gut feeling (this is a system one process in our analysis above). This is the somatic marker.

The marker forces attention onto the negative outcomes, and generates a warning signal. This signal may lead you to reject the option out of hand.

Effectively it rules out certain paths, protecting you from future loss, and allowing you to choose among the remaining possibilities. The absence of somatic markers creates the inability to choose between decisions, because all are examined in intricate detail, as Damasio found with Elliot.

Damasio and his colleagues devised a clever experiment to see how the responses of patients with damaged prefrontal cortexs compared with normal people with regard to the creation of somatic markers. Each player was sat in front of four packs of cards (packs A, B, C, D). Players were given a loan of $2000 and told the object of the game was to avoid losing the loan, whilst trying to make as much extra money as possible. They were also told that turning cards from each of the packs would generate gains, and occasional losses. The players were told the impact of each card after each turn, but no running score was given.

Turning cards from packs A and B paid $100, whilst C and D paid only $50. However, certain cards in A and B resulted in a major loss, sometimes as much as $1250. The equivalent losses in packs C and D were much smaller, an average of $100. These undisclosed rules were never changed. The duration of the game was 100 turns, although this information was also withheld from the players.

When normal people played the games, they started to sample each pack. Then presumably lured by the big payoffs started to use A and B more and more. However, within the first 30 moves, they had switched their preference to the lower packs C and D. The very high cost of cards in A and B seems to deter normal players.

When players with damage to the prefrontal cortex played the game, very different outcomes were observed. They tended to concentrate on packs A and B, regardless of the large losses incurred. In fact, in most games, by the halfway point most of these players had gone bankrupt.

Effectively, the prefrontal damaged players seem to lack the ability to create somatic markers for avoiding the high risk packs. Although they are still sensitive to both punishment and reward, they can't create the associations necessary for avoiding the tendency for the most immediately rewarding option. In some sense, they have lost their self control, and their ability to make decisions.

Emotion seems to be central to our ability to actually make decisions. LeDoux writes "While conscious control over emotions is weak, emotions can flood consciousness. This is because the wiring of the brain at this point in our evolutionary history is such that connections from emotional systems to the cognitive systems are stronger than connections from the cognitive system to the emotional systems."

A small (but thankfully vocal) group of psychologists and economists have been pursuing the role of emotion in the generation of heuristics and biases. Two very recent and excellent examples of this approach are Loewenstein et al (2001), and Slovic et al (2002).

For instance, Loewenstein et al (2001) write

> Responses to risky situatios (including decision making) result in part from direct (i.e. not cortically mediated) emotional influences, including feelings such as worry, fear, dread, or anxiety...feeling states are postulated to respond to factors...that do not enter into cognitive evaluations of the risk and also respond to probabilities and outcome values in a fashion that is different from the way in which these variables enter into cognitive evaluations. Because their determinants are different, emotional reactions to risks can diverge from cognitive evaluations of the same risks.

Whilst Slovic et al (2002) write

> Images, marked by positive or negative affective feelings, guide judgement and decision making. Specifically, it is proposed that people use an affect heuristic to make judgements. That is, representations of objects and events in people's minds are tagged to varying degrees with affect...affect may serve as a cue for many important judgements.

Imagine a situation where you can win a prize by taking a red jelly bean from a jar. When presented with such challenges, participants often preferred to draw from a bowl containing a higher absolute number, but a smaller proportion, of red beans (e.g. 7 in 100) than from a bowl with fewer red beans but a better probability of winning (e.g. 1 in 10).

Slovic et al interpret this as suggesting that "images of 7 winning beans in the large bowl appeared to dominate the image of 1 winning bean in the small bowl...consistent with the affect heuristic, images of winning beans convey positive affect that motivates choice".

Why are the emotional connections dominant in an evolutionary setting? The answer seems obvious. The emotions are more important to our survival than the pure cognitive process. Think about the emotion of fear example that I explored earlier. If the system one response is faster (albeit inaccurate) it will keep us safe. Yes, it may lead us to some false positives in statistical parlance, that is to say, it may identify some situations as hazardous that actually are innocuous. However, false positive rarely kills in this context. It is better to be safe than sorry or the quick and the dead if you prefer. LeDoux has shown that in rats the reaction time of the "low road" is half of that of the "high road". Hence we have become evolutionarily tuned to listen to our system one responses.

What of the other heuristics and biases outlined under the heading of heuristic simplification? It strikes me that economists' devotion to rationality is bizarre. After all economics is a science concerned with the allocation of scarce resources between competing claims. Our mental capacity is limited, so we need to allocate over many tasks.

Economists should be all too familiar with the concept of maximising subject to constraint. In this case, our constraints are our limited mental capacity ranging from memory, to attention and perception. So surely an economist thinking about thinking would suggest that some form of limited rationality is the proper way to model the mind, rather than blithely assuming the Vulcan like logic ability that is standard (however, unobtainable!)

For instance, limited attention can help explain saliency effects, anchoring, and slow adjustment. That is to say, because we as humans have a bound on our ability to pay attention we will find ourselves occasionally drawn to things that shouldn't concern us (saliency effects), when we find such things capturing our attention we will tend to hold onto them (anchoring effects). Once we have anchored we will adjust away from this benchmark only very slowly.

Evolution has not created us to be machines, it has driven us to maximise our fitness. In order to do this it has placed emotions at the very centre of our thought making process. Plus, we should not think of ourselves as machines with boundless capacity to calculate and optimise. Indeed "economics" would suggest a far more modest solution than total rationality… if only economists would follow the logic of their own discipline!

I admit I have strayed far from the evolutionary basis on which I started. So it is time to return. Why is it that psychologists such as Kahneman and Tversky have uncovered such a wide range of common errors in our thinking patterns?

The simple answer is we often simply don't understand probability very well. We as a species are generally probability blind. Probability in its current form really only surfaced during the eighteenth century thanks to the Reverend Thomas Bayes. That is a mere nanosecond on an evolutionary time scale. Our brains simply have evolved to think in probabilistic terms. Against the backdrop of the evolutionary ancestral environment, would we have needed to deal with any form of probability? We just won't have any use for such a skill.

Just as we saw with the Wason selection test used by Cosmides and Tooby, the presentation of the data matters. Virtually everyone can solve the Wason selection test when it is framed as a cheater detection test, but put it into a different format and only around ¼ of people can solve it.

Some psychologists (so called ecological rationalists) seem to think because we can solve problems when they are presented in one form, then we shouldn't worry about the errors stemming from solving similar problems in different formats – that biases aren't really biases.

I would disagree. Our minds are modular. Each module is adapted for some purpose. However, when we don't recognise the problem as coming from that particular class we find it hard to solve. This seems to be what happens in many of the biases that result from heuristic simplification.

Let's start with an example of probability blindness. Consider the following (taken from Gigerenzer (2002)):

The probability that a woman has breast cancer is 0.8%. If a woman has breast cancer, the probability is 90% that she will have a positive mammogram. If a woman does not have breast cancer, the probability is 7% that she will still have a positive mammogram. If a woman has a positive mammogram, what is the probability that she actually has breast cancer?

If you were a perfect Bayesian you would immediately come up with the following formula:

P(disease|positive)=(P(disease)P(positive|disease)/(P(disease)P(positive|disease)+P(no disease)P(positive|no disease))

No wonder we are probability blind!

In numbers:

(0.008*0.9)/(0.008*0.9+0.992*0.07) = 9%

Gigerenzer points out that if we express the problem in natural frequencies we can solve it simply. The problem becomes:

Eight out every 1,000 women have breast cancer. Of these 8 women with breast cancer, 7 will have a positive mammogram. Of the remaining 992 women who don't have breast cancer some 70 will still have a positive mammogram. Imagine a sample of women who have a positive mammogram. How many of these women actually have breast cancer?

In natural frequencies Bayes Law simply becomes:

No. of true positive tests / (no. of true positive tests + no. of false positive tests)

In numbers:

7/(7+70) = 9%

Natural frequencies have the advantage that base rates are automatically built into the calculation which simplifies Bayes' Law no end. Indeed it is easy to make a case that stats teachers could improve their classes' understanding (and ease their own pain at teaching Bayes'Law) if they taught people to reframe probability questions into natural frequency problems.

Moving from probabilities to natural frequencies can also alleviate the conjunction fallacy (part of the representativeness heuristic). The original formulation (Tversky and Kahneman, 1983) is:

Linda is 31 years old, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in antinuclear demonstrations.

Is it more likely that Linda is a bank teller
Or
Is it more likely that Linda is a bank teller and active in the feminist movement?

In general, most people go for the second option (around 85% of participants in actual fact!) The same problem can be expressed in natural frequency terms as follows:

Linda is 31 years old, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in antinuclear demonstrations.

There are 100 people who fit the description above. How many of them are
bank tellers?
bank tellers and active in the feminist movement?

Hertwig and Gigerenzer (1999) find that the effect of expressing the problem in these terms is dramatic. They report moving from 80-90% conjunction violations when the problem is expressed in its first format to 10-20% conjunction violations when it is expressed in the second format.

So why are natural frequencies natural to us? What was it our the ancestral evolutionary environment that drove to us to be capable of dealing with natural frequencies?

The very nature of our origins suggests why we might find natural frequencies easier to deal with. Imagine a human in the ancestral evolutionary environment, remember these people were largely hunter-gather groups. Like all animals, a large proportion of each day would have been devoted to feeding. As early humans went from day to day they would have been sampling potential food sources, and learning the cues (signals of potential food sources such as certain types of vegetation). This is nothing other than natural sampling, the updating of frequencies from observation to observation. Natural frequencies report the "to date" tally of the natural sampling process. Hence counting the number of times you got ill from eating a certain plant, or finding a food source close to a forest would have improved your fitness.

Social Interaction

The final source of biases identified at the outset was our social nature. In particular we will be looking at imitation and the role of culture. By culture I mean simply an inherited stock of knowledge that is transmitted from one generation to the next.

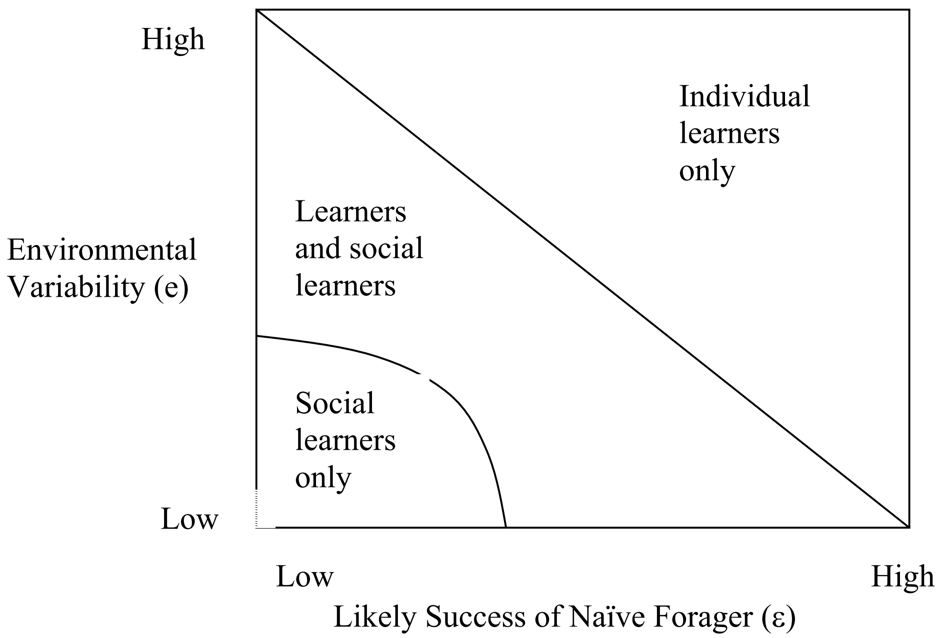
There are many examples of culture in this sense, and indeed imitation in the animal kingdom. For instance, the other day I was watching David Attenborough's Life of Mammals. The particular episode I was viewing showed how a herd of elephants were passing on their culture to the next generation. The elephants in question were from Mount Elgon in Kenya. In order to obtain vital salts these elephants follow a most incredible journey.

> Elephants for centuries have visited a cave here. They boldly walk into its depths, along a passage so long and winding that no natural light reaches far into it. In any case, the elephants usually visit the cave at night…Elephant calves usually stay close to their mothers and so they too walk deep into the caves…But it is important they make the journey, so that they will learn the route into the cave and be able to maintain the tradition. (Attenborough, 2002)

Imitation serves not only to transmit information vertically through the generations, but also transmits information horizontally through the social group.

Nor is the role of imitation restricted to so called higher order animals. Lee Alan Dugatkin has spent an inordinate amount of time studying guppies. Even guppies with brains the size of pinheads show signs of imitation. In particular Dugatkin (2000) shows that in mate selection in guppies, imitation can be a highly powerful force. He finds that female guppies are pre-disposed towards males with a more orange colouring. However, he also finds that there is a marked tendency for female guppies to imitate each other. In that so long as a male has a threshold level of orange colouring, females will tend to prefer males which other females had chosen to mate with. Guppie culture at its best!

Laland et al (1996) use a mathematical analysis of population genetics models too explore when natural selection should favour horizontal social learning. They find that two key variables transpire to be (i) the probability that a naïve forager will successfully locate a highly nutritional but patchily occurring food source (ε) and (ii) the rate at which the environment varies (e).



Source: Laland et al (1996)

Environmental variability in this model is defined as the rate of daily or more frequent foraging trips. So even very low levels of e can indicate rapid environmental changes. In general Laland et al suggest that social learning can evolve in a rapidly changing environment when the likely success of a forager is also low either because individuals can only search small areas of the population range or because the food source is very widely distributed.

Dugatkin (2000) points out that social learning is much faster than natural selection. Natural selection works over multitudes of generations, whereas social learning spreads more like a virus. Because of this differing speed of transmission, Dugatkin argues that genes are more likely to dominate in a stable environment, but when the world around us is changing rapidly then we are more likely to witness social learning becoming the dominant feature. This certainly makes sense in terms of the increasing frequency with which we have witnessed the occurrence of bubbles in financial markets over recent years.

Could our brains have evolved to listen out for gossip? Could this explain why we are so prone to falling for rumours? Steven Pinker, one of the shining lights of the evolutionary psychology approach argues that gossip played a vital role in the evolutionary ancestral environment. He writes "Gossip is a favourite pastime in all human societies because knowledge is power. Knowing who needs a favour and who is in a position to offer one, who is trustworthy and who is a liar, who is available…and who is under the protection of a jealous spouse…- all give obvious strategic advantages in the games of life. That is especially true when the information is not yet widely known and one can be the first to exploit an opportunity, *the social equivalent of insider trading*." (my italics).

Not only is social learning likely to have emerged from our evolutionary past via genetics, it may also have arisen from the existence of a second replicator. This will need a little explaining. Genes are the primary replicator, that is to say genes are trying to reproduce themselves in each subsequent generation (see Dawkins, 1976). A replicator must meet three criteria (i) fidelity (good copies are made), (ii) fecundity (lots of copies are made) and longevity (copies are made for a long time). Dawkins suggested the possible existence of a second replicator in the final chapter of his masterpiece, The Self Gene. He referred to this second replicator as a meme.

The Oxford English Dictionary defines a meme as “An element of culture that may be considered to be passed on by a non-genetic means, esp. imitation”. Memes are effectively contagious ideas.

Memes have now taken on a life of their own (a mimetic meme, if you like). Daniel Dennett (the America philosopher) has adopted memes as the corner stone of his approach to consciousness (see Dennett (1991,1995)). For a book length treatment of the meme, readers can do no better than Blackmore (1999).

Once we accept that memes are a second replicator then we can stop thinking that cultural transmission is always selected by genetic fitness considerations. Memes are interested in making more copies of themselves, and ensuring their survival into the next generation, in a fashion similar to genes, but with condiseration to mimetic fitness rather than genetic fitness.

Memes are a powerful tool for understanding much that doesn’t make sense in terms of genetic fitness. For instance, a religion that enforces celibacy upon its preachers it clearly at odds with genetic fitness, as there can be little hope for the survival of genes to the next generation. However, in terms of mimetic fitness having a dedicated mouthpiece (without the distraction of sex) is surely a key survival strategy.

Evolutionary psychology argues that our minds are domain specific to our past environment. When we act in maladaptive ways today, it is simply because our brains aren’t tuned to handle the world in which we find ourselves.

Accepting the role of memes as a second replicator complicates matters. Memes have effectively co-opted a ride on our evolutionary ability to imitate. The ability of humans to communicate is central (Pinker, 1994) to our evolution. Indeed Diamond (1992) argues that the “Great Leap Forward” in terms of evolution was the creation of language (and accounts for why we outmanourved the Neanderthals, who, contrary to popular opinion, seemed to have larger brains that us!).

Once we have speech and the ability to imitate, then the possible role of a second replicator emerges as a major evolutionary force. This in turn means that we are faced with the possibility that maladaptions are in fact not maladaptions but rather the result of memes lurking in our minds.

Conclusions

I would argue that both memes and genes have a role. In terms of the foundations of heuristics and biases I find the evidence of evolutionary psychology compelling. The way we think is largely determined by our past. That said, memes have a large role to play in many areas of social interaction. Given the rapidity with which the world is changing, the role of social learning may become dominant in the future. In order to understand future developments a good understanding of our past, and memes is likely to be key.

Can anything be done to mitigate the maladaptions that we currently find? As we have shown above, framing is perhaps the key problem we must overcome. This in turn suggests that we need to spend far more time teaching our children how to think, and think critically (if memes are to be exposed). However, debiasing is always easier said than done!

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