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The Biology of Resilient Beliefs

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Some beliefs seem to be more resilient to change and extinction than others. This paper argues that some of the strong beliefs held by humans have deep biological roots in our evolutionary past, and the neuronal pathways and structures that support them can be found in other species. This paper describes four basic universal criteria present in persistent beliefs: intuitibility, predictability, reliability and utility (IPRU). The paper argues that the study of belief as a modern scientific discipline will require consideration of the evolutionary context through which the neural pathways associated with belief formation, maintenance and endorsement have emerged. We also suggest that the study of religious belief has discouraged the adoption of an overarching framework for understanding our belief system in all its breadth. Our approach incorporates evolution-driven cognitive and affective biases, attachment mechanisms and reward expectation. Rather than operating as genuinely adaptive phenomena associated with evolutionary advantage, we suggest that belief systems emerge as a by-product of evolutionary pressures.

Keywords: Intuitibility. Predictability. Reliability. Utility. Evolutive Framework.

A biologia das crenças resilientes

Há crenças que parecem ser mais resilientes a mudanças e extinção do que outras. Este artigo argumenta que algumas das crenças humanas mais fortes têm raízes biológicas profundas em nosso passado evolutivo, e que vias e estruturas nervosas que as suportam podem ser encontradas em outra espécie. Este trabalho descreve quatro critérios universais básicos nas crenças persistentes: ser intuitiva, ser previsível, ser confiável e ser utilizável (IPRU). O trabalho argumenta que o estudo de crença como uma disciplina moderna demandará considerações sobre o contexto evolutivo, através do qual emergiram vias neurais associadas à formação, manutenção e apoio à crença. Também é sugerido que o estudo da crença religiosa tem desencorajado a adoção de um contexto abrangente para a compreensão de nosso sistema de crença em toda a sua profundidade. Abordagem aqui utilizada incorpora viés cognitivo movido pela evolução assim como viés afetivo, mecanismos de fixação e expectativas de recompensa. Sugerimos que os sistemas de crença emergiram como subproduto de pressões evolutivas, ao invés de operar como um processo genuinamente adaptativo associado a vantagens evolutivas.

Palavras chave: Intuição. Previsibilidade. Confiabilidade. Utilidade. Contexto evolutivo.

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Introduction

In recent years there has been increasing interest in the study of religious belief. This area of scholarship appears to be growing in visibility and influence suggesting a need to consider carefully implications arising from evolutionary and cognitive science for the study of religious belief (Barret, 2007). In common among these theories is the idea that humans are hardwired to believe in gods and to embrace religion (Attran, 2002; Wilson, 2002; Persinger, 2003; Dennett, 2006; Murray, 2008; Nelson, 2011). However, this is arguably an over restrictive approach to the study of belief, because it focuses exclusively on one single form of belief. We subscribe to the view that religion spreads among humans not because of an alleged innate tendency to believe in gods, but because the beliefs that compose every religion, in common with an array of non-religious beliefs, confer adaptive advantage.

Among the several definitions, which vary by academic field, philosophical approaches have a tendency to define belief within a framework of necessarily *human* mental states. Some authors claim that belief cannot exist without the presence of phenomenal consciousness or rationality (Worley, 2008). A belief is widely defined as a claim that is held as true. This anthropocentric definition disregards the ability of other species to hold beliefs. The word *claim* assumes complex language based on human speech and the word *truth* is difficult to define. An evolutionary and biological approach to the study of belief requires a definition that spans across species and highlights the causal processes in the brain that support their formation. Alcock (2003) proposes that a belief is simply expectancy about something and that this expectancy is possible to study through the employment of neurobiological methods.

In line with Alcock, we propose that a belief is formed when the acquired information is perceived and acted upon as being reliable. This approach allows for the formation of beliefs in species that pass information on to conspecifics and act upon that information. This approach includes the evolution of communication and signalling mechanisms.

Beliefs are formed through the acquisition of information via passive observation or the reception of meaningful signals sent by others. The concept of meaning is here defined as information that is decoded and understood by the receiver of a signal. When those information-loaded signals are propagated and incorporated in the memory of other receivers, they become memes (Dawkins, 1976). In this paper the word meme is used as a shortcut to refer to information that is passed from mind to mind and spread in a population.

Some beliefs are very difficult to eradicate even when contrary evidence is presented. Examples of this are beliefs held by supporters of intelligent design, young earth creationists, and adepts of dogmatic political theories holding such beliefs. Paradoxically, followers of doomsday cults seem to grow more committed and convinced of their beliefs when they wake up alive and well after the expected date of world destruction (Festinger *et al*., 2012).

I propose that the success and resilience of beliefs depend on two main processes: the memetic virulence of a meme and traits inherent to the meme itself. The concept of memetic virulence proposed by Dawkins (1976) is akin to the success of a virus in propagating itself successfully through a population. In accordance with this view, the virulence of a meme should be modulated by external and internal factors; the external factors are those outside the control of the host such as time of social imprinting, repetition, ritualization, group structure and the transmission process, whereas the internal factors refer to the processes occurring inside host itself and they

may refer to the host's tendency to accept information more or less uncritically, and its received meaningfulness.

Two other classes of factors make a belief difficult to eradicate. The first focuses on persistence or resilience processes. These are external factors that contribute to the persistence of the idea in the minds of a population as for example is conferred via repetition, ritualization and peer pressure to conform. The other class of factors is inherent to the content of the meme, i.e. the narrative or the idea that appeals to the minds of the hosts. Persistent beliefs are here understood as beliefs that are difficult to change or eradicate. They share universal features which can be categorized according to four properties; "intuitibility", "predictability", "reliability" and "utility" (the IPRU system), which are the focus of the discussion of this paper.

Intuitibility

Intuitibility is a here defined as a property of beliefs that aligns with intuition. In psychology the term *intuition* is used to describe thoughts and preferences that come to mind quickly and without much reflection and reasoning. In lay terms intuition is that hunch of "rightness". Beliefs that appeal to a feeling of rightness are resistant to rational critical appraisal because they trigger emotional attachment to the semantic content of the message. That intuitive feeling of rightness is triggered when we perceive information that conforms with our pre-established conceptions of the world, especially to what we have been exposed to and learnt during mental development. In adulthood, beliefs analogous with earlier cultural exposure are more automatically assimilated. This is usually known as confirmation bias. But there is a kind of knowledge that is not learnt, it is entrenched in the neural networks of individuals. For example, the processes that enable us to assess risk, to categorise the entities that surround us, or attribute agency to events of unknown cause, they are necessary mental operations that give meaning to perceived information. These faculties can be said to be "hardwired" because, as argued later, they are shared with other animal species.

Folk physics, folk psychology and folk biology are all expressions of these sources of intuitive knowledge. Folk biology reflects the natural tendency to categorize the world and organise it into classes sharing similar traits. Tribal societies have systems of classification of plants and animals according to functional properties. Some plants are good to eat, others to purge, others are dangerously poisonous (Medin and Atran, 1999).

Folk physics is the natural tendency to understand the behaviour of objects and physical phenomena. The perception of gravity creates an expectation that objects fall downwards, that they do not normally float in space and that some absorb water while others are impermeable and displace water. Infants seem to understand that solid objects do not pass through other solid objects (Baillargeon, 1994) and that things do not vanish without trace. This explains why magic has such an effect of awe and wonder, because it violates the expected behaviours of objects subjected to the laws of physics. The way chimpanzees perceive the physical properties of the world, suggests a close similarity to the cognitive abilities of humans (Povinelli, 2000).But folk physics can also be misleading precisely because it is rooted in intuition. When asked the question "what falls faster in the vacuum, a feather or a stone?" the tendency is to answer stone. People have not evolved in the vacuum so there is no reason why the brain would have developed an ability to understand the behaviour of objects in such conditions.

Folk psychology is the ability to understand, explain and predict the "behaviour and mental states" of other individuals and as such requires a capacity to create a the-

ory of what is going on inside the minds of others (Theory of Mind or ToM). Children as young as 6 months seem to have an ability to attribute mental states to animated and inanimate items (Wellman, 1990) as do so many other animal species. Recent studies in animal behaviour suggest that primates and other social animals have some rudimentary forms of ToM.

Folk psychology also offers categorisations of people's behavioural traits and the first one documented can be traced back 2,500 years to the Ancient Greek physician Hippocrates, classifying human temperaments into sanguine, choleric, phlegmatic and melancholic. Since then, many classifications of personalities have been offered suggesting different approaches to organize and describe behaviours, from astrological profiles to scientific descriptions of personality types.

Animals that live in social groups need to recognise the behavioural traits of each individual. They need to distinguish good co-operators from free-riders, who to hook up with and who to avoid. But a no less important characteristic of social living is the tendency to follow leaders who hold information that is useful to others. They may know about drinking and foraging places, good hides, or how to avoid danger. The leader is an invaluable information centre on which the other members of the group can rely. The natural tendency to follow is also expressed in human societies. But leadership in humans and other animals is based on a trade-off between responsibility for group survival and the privileges acquired from such status. The leader that does not continue to deliver will eventually be dismissed and others will compete for the position (see for example de Wall, 1982). Although the tendency to follow a leader may be described as a natural instinct in animal societies, the leader's selection is most likely to follow a process that appeals to intuitive processes.

In summary, when novel information is acquired it is automatically compared to the mental database of previously stored information. If this new information is congruent with what is already known, it provides a feeling of rightness. It is important to emphasise that this comparative process does not necessarily need any form of conscious rational appraisal.

Is intuition hardwired knowledge?

When we claim that intuition is "hardwired" this does not mean that behaviours are unchangeable. Here the word 'hardwired' means that there is a neurological architecture that supports and processes behaviours that promote survival. It is also important to clarify that intuition is not the same as instinct. Instinct is when naïve animals seem to know what to do without learning. Egyptian vultures throw stones at ostriches' eggs in order to break them and feed on their contents. This is a behaviour that is not learnt, and naïve animals seem to know what to do when presented with an egg for the first time (Thouless and Fanshawe, 1989), but there is a difference between the motivation to throw stones (instinct) and knowing the size and weight of the right stone (intuition); the latter comes with experience.

Intuition has been studied in risk assessment, evaluation of truth, and moral decision making. In these studies the tested subjects are asked to evaluate options and make decisions based on their intuitive decision making rather than the use of rationality or logic. It was observed that patients with lesions in particular areas of the brain such as ventromedial pre-frontal cortex (Goel *et al*., 2003; Harris *et al*., 2008; Langdon *et al*., 2013) and orbitofrontal cortex (OFC) dysfunction are less likely to make the right intuition-based decisions (Bechara *et al*., 1994).

Intuitive Morality

Perhaps some of the most important human beliefs concern morality. Morality has been credited as an exclusively human trait, but this assumption has been progressively abandoned due to research on the evolution of behaviour. Altruism, compassion and justice are deeply rooted in the biological processes that regulate behaviours such as co-operation, empathy (Zaki, 2014) and fairness (Wynne, 2004; de Wall, 2009; Brosnan and de Wall, 2012; Range *et al*., 2012), and these are present in many other species. The development of Game Theory and its application to research on the evolution of co-operation provides plausible explanations for the evolutionary origins of altruism (Axelrod and Hamilton, 1981; Maynard-Smith, 1964, 1982; Dugatkin, 1997; Nowak, 2011). But even if mathematical models offer plausible explanations, they do not reveal which biological mechanisms natural selection is acting upon. Recent neurobiological studies highlighted the role of oxytocinin regulating co-operative and affiliative behaviours, by focusing on the biological process regulating reward and attachment (Baumgartne *et al*., 2008; for further discussion, see Rilling, 2011).

The idea that the Golden Rule is a cultural product of Christianity is widespread in the western world. This presents a narrow vision of morality, which ignores Classical Greek philosophy and evolutionary theory. There are several expressions of this rule, but basically it can be summarised in the simple maxim, "do not do to others what you do not want done to yourself". The reverse of this rule can be expressed as tit-for-tat which is an evolutionarily stable strategy (ESS) in games like the Prisoner's Dilemma (Maynard-Smith, 1982).The Golden Rule is no more than a heuristic that works in every social context where there is a conflict of interests between individuals and not necessarily a principle of any particular religious creed.

Contrary to what has been previously defended by philosophers such as Kant and Descartes, morality might not be the result of reasoning, but it is more likely to follow Hume's suggestion that it is a post-rationalization of our deepest emotions. Biological evidence consistent with this view has been reviewed by Haidt (2001).

2. Predictability

A certain level of predictability is necessary for planning for the future, and the memory of accumulated experiences shapes decision making, creating enduring beliefs. Any idea that induces us to believe we have control over the potentially aversive events that affect us is very powerful because it contributes to a reduction in anxiety (e.g., Seligman *et al.,* 1971; Johnson, 1973; although see Thompson, 1981). Experimental evidence from conditioning studies is consistent with this view, indicating that uncertainty about outcomes promotes fear and general anxiety (e.g., Barlow, 2000; Grillon, 2002; Grupe and Nitschke, 2013; Rosen and Schulkin, 1998).

It is important to clarify that the word *predictability* encompasses two concepts:

i. the objective characteristics of environmental stimulation (i.e., signals received from the environment, such as seasonal change, etc.) and
ii. the subjective interpretation of what those signals signify (which will influence subsequent response/behaviour).

The first provides the foundation to the latter. As a database of patterns is accumulated in memory, they serve as the substrate from which to extrapolate future outcomes on the basis of those recognised features. The foraging behaviours of many

animals depend on this ability. Migratory and mating patterns depend of the predictability of the seasons. In summary, survival depends on the ability to make the right decisions at the right time based on information that is perceived as occurring regularly. However, these decisions do not have to be conscious, as is shown through the observation of behaviours that obey the predictions of optimality models (Krebs and Davies, 1991). The conscious awareness of spatial and temporal patterns is perhaps a trait recently acquired in evolutionary history. From accounts of animal behaviour studies, it is well established that animals have an ability to make decisions for the immediate future (e.g. timing of nest building, migration, food storage), but it is impossible to ascertain whether these decisions are conscious or not.

Autobiographical memory and the ability to predict personally-relevant future events require subjective mental 'time travel'. These are complex functions which require complex cognitive capacities such as meta-representation, self-awareness, mental attribution, understanding the perception-knowledge relationships, and dissociation of imagined mental states from one's present mental state in the service of truth/objectivity (Suddendorf *et al*., 1997). It has been suggested that such level of cognitive sophistication might have occurred very recently in hominid evolution between 75,000 and 50,000 years ago (McBrearty, *et al*., 2000; Henshilwood *et al*., 2003; Hill *et al*., 2009), so it may be reasonable to assume that other animal species might not have an ability for awareness of the future, but we cannot rule out that evolution on other animal species might also have selected some level of awareness of future events as studies on corvid cognition have suggested (Correia *et al.*, 2007; Dally *et al*., 2005).

What are the advantages of belief in the predictability of future events?

Knowing allows for planning for whether the future s associated with positive or negative outcomes. The assumption that planning is indeed possible contributes to the perception of having a certain degree of control over candidate outcomes.

As indicated above, any belief that offers certainty about what to expect may reduce stress. This explains why the dark arts of divination, tarot reading and astrology are so pervasive in our society. Such beliefs address our deepest fears, including fear of disease and death. Religion as much as science offers solutions aimed at producing enhanced predictability and control over unexpected or random events. Meteorology provides a good level of predictability over weather events, medicine predicts the survival from certain diseases, social sciences and economics attempt to identify behavioural patterns in human populations, which help planning for the future.

The anxiety associated with the uncertainty of what comes after death maybe decreased by a belief in an immortal soul which assumes a binary outcome; the soul either ends up in a blissful paradise or a terrible fire of eternal suffering. But despite the bleak possibility of hell, it is still less stressful to know what is to come than not knowing. We have a tendency to think in either-or dichotomies. This provides at least 50% probability of knowing the outcome, whereas not knowing provides 0% of certainty. Beliefs based on hope may be very adaptive at times, for they fend off feelings of helplessness and depression, and may even allow the channelling of one's energies into finding effective ways to deal with the danger (Alcock, 2003). A number of behavioural and mental processes confer directly or indirectly some predictability, for example;

- Anticipatory behaviours
- A sense of control (over environmental or social events)
- Understanding the cause
- Identifying agency and intentionality
- Purpose and meaning

Anticipation of positive or negative consequences

Anticipatory mechanisms are probably one of the most ancient forms of behaviour regulation in evolution. The anticipation of what is to happen reduces anxiety, whether the outcome is positive or negative. When humans believe in promises, they undergo a mental state which involves anticipation. For example a prophecy is a type of a promise which confers a belief in a certain degree of predictability. If the outcome is expected to be good, it works as a motivator but if it is expected to be bad, it offers an opportunity to prepare for what is expected, yielding a false sense of safety. Promises and prophecies reduce the unexpected component of surprise because when people imagine a future event they project an expected hedonic response (Buechel *et. al*., 2013). But if the outcome is expected to be negative, then people can prepare for the event and cope better with stress. This theory was tested in an experiment with rats examining the importance of warning signals in coping with electric shocks on the tail. Animals that were given a warning signal prior to the shock had less stomach ulcerations than in the no-signal condition (Weiss, 1971). However, a study on monkeys by Brady (1958), suggested that monkeys with control over a lever to prevent electric shocks developed more ulcers and had less coping ability than the group that had no control.

These classical experiments provide models to explain seemingly contradictory results and one must be careful in extrapolating them to condition subject to multiple aspects that define the different types of beliefs. The issue is not if knowing whether the negative or positive qualities of the outcome reduce stress. It is about knowing what the future reserves us so we can plan for the outcome.

Control as a means of achieving predictability

Averil (1973) described three main types of control: (1) Behavioural control, which pre-supposes a direct action on the environment, (2) Cognitive control, reducing uncertainty and imposing meaning on events and (3) Decisional control, providing a choice among alternative courses of action.

It is well known that the lack of control leads to negative physiological and behavioural stress responses such as a rise in the activity of hypothalamic–pituitary–adrenal axis (Broom *et al*., 1993),or earned helplessness(Seligman, 1972). Such indicators can be brought to normal values when animals are given access to control mechanisms such as places to retreat to avoid bullying by conspecifics, opportunities to express normal behaviours and to operate mechanisms that provide environmental comfort such as thermoregulation or avoidance of noxious stimuli. In experimental conditions, much of this control is obtained through operant conditioning (see for example Baldwin and Ingram, 1968; Baldwin, 1979). Offering alternatives which convey some impression of control over choice and decision making, can significantly improve welfare (Fraser and Broom, 1990; Basset and Buchanan-Smith, 2007).

It is well established that in human societies perceived lack of control leads to undesirable physiological responses (Heckhausenand Schulz, 1995; Maier and Seligman, 1976). Enabling a sense of control over events enhances well-being, an ability to cope with stress through a reduction of anxiety and decrease in the perception of

pain (Fiske and Taylor, 1991; Glass *et al*., 1973; Luck, *et al*., 1991), and even promoting longevity (Langer and Rodin, 1976).

Social control

If a lack of control over one's life and the surrounding environment induces negative responses, it would be reasonable to expect that having control would promote personal wellbeing. In a comprehensive review on the effects of behaviour control on the neurochemical responses of the brain Maier (2015) provided evidence that a sense of control limits the impact of the stressor agent.

Social control is one of the many strategies that produce group stability, weeding out non-conformists through the enforcement of behavioural homogeneity. Beliefs, congruent with this need to control others, are useful to support aspiring leaders.

Social control is a behaviour observed across many social species among mammals and birds for it promotes social predictability through the observation and enforcement of rules that contribute to group cohesion. In humans the same behaviour is expressed from small groups to large religious and secular systems.

Social groups operate through two distinct self-preservation strategies: Intra-group dynamics focuses on co-operation and punishment of free riders, whereas inter-group dynamics focuses on competition and exclusion of out-group members. Beliefs that promote in-group cooperation and out-group elimination are aligned with intuitive thought. But in-group tensions are also a frequent occurrence especially in situations where unfair distribution of resources and free-riding are an issue. When this happens, punishment becomes a method of enforcement of social cohesion. Other forms of enforcing group cohesion are coercing a community to think homogeneously. In these circumstances, homogenous thinking becomes the biological equivalent of scent marking and kin recognition in other social species.

Note that natural selection acts on the behaviour, not on the belief. If the narrative content of the belief changes, this is due to cultural evolution, not natural selection. The narrative that embodies the belief simply mirrors behaviours that have been naturally selected. However, there is a dark side to such strategies; memetic homogeneity breeds intellectual stagnation and hampers cultural evolution

Obedience; peer pressure and appeal to authority

When people lack the ability to exert personal control, they seek help from external trusted entities (e.g. leaders or mystical entities), which will eventually deliver the goods, after some negotiation based on different types of offerings. For example, among Catholics, unidirectional negotiation with God is a frequent element of prayer, where the prayer offers to pay the favour only if the desired outcome is provided. However, control over others is only possible when those others are predisposed to accept such authority.

The sense of control may bring some relief from stress; however, having control over groups of individuals may also result in adverse stress responses. For example, in social animals the reproductive benefits of holding a harem is largely undermined by the amount of energy used to keep away competitors (e.g., sea lion and red deer harems). This type of stress is also visible among human leaders. Not only do they have to cope with the stress of decision making involving many people, but they are also acutely under the scrutiny of competitors. For this reason some people may prefer to leave control to others as we will see later.

It would be logical to assume that deciding between which of these strategies

to adopt, control or obey, depends on the trade-off between the levels of anxiety and the positive returns each strategy provides. However there may not always be freedom of choice between strategies limiting the options to conforming and allowing the group to shape the individual's behavioural model or leaving its protection.

The tendency to conform was tested in Asch's experiments which predict that a subject who has neither ability nor expertise to make decisions, especially in a crisis, will leave decision making to the group and its hierarchy. This type of obedience occurs when an individual accepts the opinions of a person believed to be an expert. This was shown by the Milgram experiments (Milgram 1963, 1965) where a subject applied apparently fatal electric shocks to a collaborator pretending to be a volunteer under orders of a supervising scientist, despite the subjects typically questioning the dangers or morality of the procedure. In this situation, he essence of obedience is demonstrated, with the individual understanding himself as the instrument for carrying out another person's wishes, thereby absolving him of any responsibility for his actions. Once this critical shift of viewpoint has occurred in the person, all of the essential features of obedience follow.

An adaptive approach to such behaviours begs the question: what is the selective advantage of total obedience? An evolutionary explanation should emphasise the tendency of social species to form hierarchies where obeying those on top of the pecking order is a strategy that prevents injury when it is not possible to keep away from their bullying. Thus, a tendency to resign to authority in humans could also be explained as a trade-off between the protection provided by the group and the need for individual control. This could explain the variation in human tendencies to submit to beliefs or to challenge them. Conforming to the beliefs upheld by the group confers an identity badge analogous to the scents of relatives, probably activating the same behavioural processes involved in kin recognition. This prompts the question, does thinking alike activate the same neurological pathways as kin recognition?

Understanding the cause: agency and intentionality

Understanding cause-effect relationships is perhaps one of the most important factors in providing some level of predictability, because it allows for planning. But the term causation is complex and goes well beyond a simple cause-effect association. The alternative approach focuses on what caused things to become what they are. These two concepts rely on different cognitive systems of increasing complexity.

Some authors emphasise the difference between causal knowledge and causal reasoning (Kummer, 1995). We prefer to avoid using the word "knowledge" because of the associated philosophical implications and prefer "know-how" since it reflects a more appropriate action-reaction response. The perception of cause and immediate effect is perhaps the most ancient form of learning in the animal kingdom. The most basic form of learning consists of the establishment of new neuronal connections when an animal learns to associate a cause to an outcome. This is known as Hebbian learning and has been widely studied in sea slugs, a large mollusc of the genus *Aplysia*. At the behavioural level, classical and operant conditioning arewidely studied and powerful forms of learning via cause--effect association. But in later stages of phylogenetic evolution, causal know-how is complemented by an ability for causal reasoning which provides the establishment of complex associations between cause and effect. While causal know-how entails a

very short time gap to establish the association in the sequence cause-effect, causal reasoning allows for a longer time gap and it also assumes the existence of an agent (animate or inanimate) triggering the event. This is an important step in the evolution of the mind, because it also requires knowledge about the properties of the agent and understanding of the difference between animated and inanimate agents. There is an evolutionary advantage in distinguishing between objects that move towards or away from the observer under their own biological motion, and those that are just randomly driven by physical carriers such as air or water currents. Evidence indicates that infants as young as 3-months old can distinguish biological from non-biological motion (Bertenthal, 1993; Bertenthal *et al*., 1984) and caused from non-caused motion (Leslie, 1982). Awareness of this difference is the root of subsequent processes that support the perception of intentionality. Things moving intentionally towards a target are probably more dangerous than things that move under the propulsion of physical agents, such as the wind or gravity. Thus the neurobiological processes that support the ability to attribute intentionality enable the evolution of systems able to frame theories of mind. Ongoing research in animal behaviour suggests that other primates, dolphins, crows, and many social mammals may also have a theory of mind (Whiten and Byrne, 1997; Heyes, 1998; Byrne, 1995; Seyfarth and Cheney, 2013) and as a consequence they can attribute agency and intentionality to other agents.

There is no doubt that all the processes referred to so far, from the simplicity of Hebbian learning to the complexity of intentionality attribution, are present in different degrees of complexity in animals other than humans, but the next step in the understanding causation is one that is arguably exclusively human. This new level requires a developed concept of intentional agents since it asks questions such as "who/what caused the world as we know it to come into existence?" This questioning requires a concept of creative processes and it involves two levels of complexity. The first level simply asks "who did it?" the next involves a higher level of cognitive complexity to ask "by which means and processes did this object come to be?" Both questions involve a concept of an intentional agent but the second question attributes another property; this agent is also a crafter. The advent of tool-making has certainly created the mental predisposition to elicit this type of questioning.

The perception of social causality and agency attribution are important in the quest for predictability. Any belief that provides answers to the above questions would address uncertainty. Thus, if random environmental events leading to ecological disaster happen, the perception of such events as the purposeful intentions of some controlling agent with capacities superior to those of humans supports the idea that they could not have done anything about it.

3. Reliability

The search for truth is perhaps one of the most puzzling features of human nature, and in order to understand this we first need to conceptualise the meaning of "truth". Adopting a reductionist stance, truth refers to reliable information.

All animals are surrounded by information some of which is perceived by their sensorial organs. When information serves a purpose or has a function which is decoded and understood by perception, then it has pragmatic meaning. If the animal acts on this information it is reasonable to assume that such information has meaning. For example, when males perceive the pheromones of a female in oestrous, this infor-

mation has meaning in the sense that it triggers the display of mating behaviours. In an evolutionary context, a signal has meaning when the information it contains is decoded by the receiver, in such a way that it triggers adequate responses. For example, the male of the Neotropical tree frog *Eleutherodactylus coqui* produces a call consisting of a two note sound, the "coqui". The "co" component is used in male-male competition whereas the "qui" note is used to attract potential mates. Males have a greater number of sound sensitive cells tuned to the "co" sound, whereas females have a larger number tuned to the "qui" sound. It makes sense that the female auditory apparatus is not tuned into detecting the male-male competition calls because such calls have "no meaning" for the female. There is no point in evolving an auditory detection system for calls that bring no useful information for the female. Nature is economic and does not spend energy in selecting for unnecessary resources. In an evolutionary context, information has meaning if it is adaptively useful (Narins and Capranica, 1976).

Mistaken information

The perception and cognitive appraisal of information from our surroundings is a characteristic of all living beings. However, with an increase in the level of complexity of the perception mechanisms there is an increasing margin of error due to concurrent appraisal devices. For example, the many optical illusions suffered by humans are the result of errors in visual perception. As we perceive these illusions we believe that what we are seeing is true. When running away from a predator requires a jump over a small gap in a gorge, a misperception of the distance between the two can mean life or death. But information is also collected from interactions with other animals and assessing the reliability of their signals is also crucial for survival. These interactions become yet more complex when errors appear not only in the appraisal mechanisms, but when the signaller induces deception on purpose, thereby producing misleading signals.

Deception

Information can be categorized according to its sources; living beings receive information inputs from the physical environment and from signals sent by others, which usually serve a purpose (communication, warning signals, calls, etc.). Signals produced by living objects are mainly targeted towards conspecifics or other threatening living beings. It is important to keep in mind that information laden signals are not an exclusive characteristic of animals. Cells, plants and fungi send chemical signals with both purposes (communication and warning). But the receiver, which needs to decode the signal, needs to have some sort of assessment mechanism which determines if the signal is reliable, for any errors in this assessment can be lethal. There are many factors that can contribute to inducing error in the receiver. Some signals are simply misperceived, others can be purposefully deceptive.

Deception in nature can occur in two ways: unintentionally and intentionally. Mimicry is an example of unintentional deception. Due to natural selection, many species develop a similarity to poisonous individuals. For example the Scarlet King snake, which is absolutely harmless, resembles the Eastern Coral snake which is venomous. This similarity (mimicry) protects the Scarlet King by deceiving predators. But this is a type of deception the snake can do nothing about. It did not choose to mimic the venomous Coral (the model). The colours of the Scarlet King are simply the result of a process of natural selection over millions of years which result in a similarity to the model.

Intentional deception is founded on a decision to engage in deceptive behaviours. Examples of these are seen in many birds which nest on the ground. Textbook examples include the Killdeer (*Charadrius vociferous*) which in the presence of predators feigns a broken-wing, or moving away from the nest adopts a false brooding position attracting the predators to a place far from the brood. These are behaviours which have been successfully selected through evolution just as much as in the colouration of the snake example, but in this case the behaviour is primed by an event which induces the animal to make a decision.

It is important not to confuse the idea of intentional behaviour with the philosophical concept of intentionality. Intentional behaviour has a purpose, or is a mental state that represents a commitment to carrying out an action or actions in the future. Intention involves mental activities such as planning and forethought (Bratman, 1987).

There are some degrees of freedom where a bird may or may not choose to display a particular behaviour, and although this choice is perhaps generated by a genetic program prompted by external triggers, there is a level of perceptive appraisal of the situation which results in a behaviour that is not exclusively automatic. This, in turn, indicates that the brain structures supporting such decision making are serve the evolution of intentionality.

Dishonest signalling

Signalling is a concept closely related to the notions of communication and information transfer, where the sender is any organism that has a biological library of signals which convey information and the receiver chooses from a set of responses corresponding to the messages enclosed in the signal. Depending on the reliability of the content, these messages can either be honest of dishonest.

Deception and dishonest signals remains a hotly debated topic in evolutionary and behavioural research. Deception in the living world is as old as the origins of multicellular life. For example, at a certain stage of the sexual cycle of the slime mould *Dictyostelium discoydeum*, the zygote giant cell (ZGC) attracts and engulfs hundreds of amoebae of the same species and feasts on them (Lewis and O'Day, 1994). This happens through the production of membrane proteins that mimic the signal for cellular aggregation, but this slime mould has evolved another form of cheating. When facing starvation *Dictyostelium* amoebae evolved cooperative behaviour contributing to the secretion of extracellular digestive enzymes which allow the whole population of amoebae to feed but in in-vitro cultures the occurrence of cheating mutants was identified. These defectors are mutant free-riders that do not secrete the enzymes but still have access to feeding (Shaulskandand Kessin, 2007).

Deception through dishonest signalling is a widespread strategy in nature, whether intentional or not, it has a survival purpose protecting against predation or allowing exploitation of resources.

The concept of dishonest signalling does not necessarily imply that an animal is aware of the falsehood of the informational content in the signal, it simply refers to signals that do not correspond to reality. For example, after losing their large claw, male fiddler crabs (*Uca annulipes*) grow a new one which has less mass, is a less effective weapon and costs less to use in signalling than an equivalent-length claw of the original form. Males with original claws do not differentially fight males with regenerated claws even though they are likely to win. Regenerated claws effectively bluff fighting ability and deter potential opponents before they fight. During mate searching, females do not discriminate against males with low-mass, regenerated claws, indica-

ting that they are deceived as to the true costs males pay to produce sexual signals (Backwell *et al*., 2000). This type of deception is not intentional and the signal is called "dishonest" just as a science metaphor to indicate that it does not convey truthful information. However, in animals with higher cognitive complexity, there is an accumulating body of evidence suggesting that individuals may engage in tactical deception producing intentionally dishonest signals especially n situations involving intra-specific competition; for example several species of birds of the genus *Parus* known by the generic name of *Titmice*, give alarm calls to clear a board feeder from competitors and gain exclusive access to food (Matsuoka, 1980; Munn, 1986).

Meerkats recognise the alarm calls made by different bird species and flee for cover when they hear them, and the fork-tailed Drongos (*Dicrurusadsimilis*) takes advantage of the situation by using both their own and mimicked alarm calls, to scare meerkats and steal their food when they have caught scorpions or geckos. (Flower, T. 2011). There are also many accounts of tactical deception in baboons (Byrne, 1990, 1995; Byrne and Whiten, 1985, 1992; Hauser, 1997).

Detecting deception

Research on the behaviour of dogs (Takaoka *et al*., 2015), captive monkeys (Hauser, 1992; Amici *et al*., 2009), dolphins and even wasps (Tibbetts and Izzo, 2010; Injaian and Tibbets, 2014) suggest that these animals can detect cheaters. As well as in animals, detection of lies by humans, seems to depend on unconscious mechanisms (Brinke *et al*., 2014).

Considering the amount of deception present in natural systems it is reasonable to assume that detection of dishonest signalling is a necessary adaptation suggesting an evolutionary arms race. Theoretical approaches based on game theory demonstrate that when a signaller can benefit from deception, the communication system is susceptible to invasion by deceptive mutants. Then listeners, faced with increasingly deceptive signals, would evolve to disregard the signal (Johnstone, 1998). In the end everyone would be lying and no one listening. However as detection mechanisms evolve, so do the cheating strategies, in an evolutionary arms-race. In a series of mathematical models Rowell, *et al*. (2006) suggested a simple model for animal communication in which signallers can use a nontrivial frequency of deception without causing listeners to completely lose belief and have shown that dishonest signalling can be a persistent outcome of a signalling interaction as a natural result of the payoffs to the parties involved.

In humans, lying can be detected through non-verbal cues. From an early age, children monitor the reliability of particular informants, differentiating between those who make true and false claims and keeping that differential accuracy in mind when evaluating new information from these people (Koenig and Harris, 2007). Detection of deception in testimony is an important area of research in forensics and crucial to crime investigation.

Punishment

The accurate detection of deception is critical to human survival (Dawkins & Krebs, 1979) and its punishment is essential to keep group stability leading to the adoption of beliefs that promote it. Beliefs that differ from those adopted by the group are perceived as deceptive and threatening. If a rogue belief cannot be eliminated, then its host has to be managed either through punishment, brain washing or group exclusion.

Group cohesion and ritual

Consistency is the hallmark of reliable information and one method of implementing it involves engaging in periodic rituals. Among their many functions, rituals aim to promote group socialization and avert deception. A willingness to invest in costly rituals provides an assurance of commitment towards shared beliefs. It is a public declaration of engagement that if broken is perceived as deception and liable to punishment and the more costly the ritual, the higher the readiness to embrace the tenets of the group.

4. Utility

A great deal of our beliefs are utilitarian. Such beliefs are strong and difficult to eradicate when they have a utility in explaining and organising the world in ways that make sense or have meaning to us, and align with our predispositions for self-preservation.

Explanatory power: How does the belief contribute to explain the world?

Perhaps one of the most puzzling questions common to most humans is "How did everything come to be?" Efforts to answer it come from two sources, metaphysics and science. Metaphysics is a branch of philosophy which endeavours to answer questions about how the world is. A sub-field known as ontology answers questions about what exists in the world. For example, while metaphysics ascertains that things fall in gravity *because of the action* of gravity, ontology establishes that there *exists* a physical force called gravity. The first explains a mechanism by which things fall; the latter establishes that a mechanism exists. Other explanations could be offered and still be part of ontology. For example if metaphysics ascertains that what makes things fly is the magic force of fairies, ontology establishes that fairy magic forces *exist*.

Metaphysical questions are present in the minds of children since early developmental stages. Between ages two and three, children develop the cognitive ability to make logical connections between things in order to understand why and how they happen. They constantly ask questions about causation, agency and mechanisms controlling processes. Any belief that provides satisfactory answers to such questions will be easily embedded in their mental development. Beliefs grounded on simplistic explanations are easier to embrace due to mental laziness. The creation of the Universe by a powerful intentional agent requires less mental energy than any explanations of how singularities and black holes shape the space-time continuum. This is because the simplistic explanation aligns with our natural tendency to see agency behind causal events. An explanation only becomes questionable when it is inconsistent with the subject's ideological framework. When explanations cause cognitive dissonance, one (the explanations) or the other (the framework) is discarded. Once in possession of an explanation, events become supposedly more predictable.

Organisational power: Organising the world through the identification of patterns and categorisation.

Beliefs that offer a sense of order have utility in the assumption of predictability. Detection of patterns, discrimination, categorisation, generalization and thinking by association are all traits that we share with many other species and are important in the founding of beliefs.

The complexity of environments we live in is dealt with by organising information in categories which focus on similarities and differences. In establishing simila-

rities, the brain looks for consistent spatial and temporal patterns organised in categories, so beliefs that offer a sense of organisation are likely to be in harmony with this cognitive trait. These are usually beliefs that offer simple functional explanations of complex systems.

The ability to categorise is not exclusively a property of humans. Many studies have been conducted on different animal species showing similar abilities. Pigeons can discriminate between individuals (Ryan and Lea 1994), categorize different types of objects (Pearce, 2008; Wynne, 2001) and even different styles of paintings (Watanabe, 2011). Dolphins can discriminate between humans (Herman *et al*., 1994), dogs categorize human gender using visual and auditory information (Huber *et al*., 2013) and human emotional states (Nagasawa *et al*., 2011), sheep (Kendrick, 1990, Kendrick *et al*., 1995) and even wasps (Injaian and Tibbetts, 2014) can discriminate between familiar and unfamiliar individuals.

Categorisation of objects, events and patterns relies on the ability to establish analogies between the observed and the model. Studies on the intelligence of corvids revealed that crows can exhibit analogical thinking (Smirnova *et al*., 2015). With the evolution of complex language, the mental processes that support the establishment of analogies bring metaphorical thinking which is a process that infuses much of religious and political rhetorical discourse.

Making sense of randomness consists of extracting information that suggests patterns and such ability may be subjected to phenotypical variability in populations. Detecting patterns brings an adaptive advantage helping to categorize and make predictions, but it can also result in negative outcomes when such patterns are meaningless as for example seeing images of faces in random shapes such as the wrinkly roughness of the bark of trees, or the shades of toasted bread. These illusions can easily become virtual metaphors for the mental constructs we believe in. Frequently, gamblers "see" patterns in things that are actually quite random and meaningless, to such a degree that they are quite willing to impulsively bet good money on such illusory cues: they do not fully grasp the random nature of the games they are playing (Wilke *et al*., 2014).

Self-preservation power

Although all animals have behaviours that contribute to self-preservation, humans are arguably the only species to develop an awareness of death as the end of life. This is a very deep and complex philosophical issue which is out of the scope of this discussion. The important point to keep in mind is that associated with the evolution of cognitive abilities that enable us to think about our own demise are many beliefs that may contribute to the eluding of death or prolonging life. In this category are those beliefs which deal with protection and healing of the body, and acquisition of resources to ensure continuity of the body and the species.

The power of healing beliefs

To stay alive one needs to adopt several strategies as for example avoiding or minimizing life threatening situations or applying panaceas when the body is harmed or at risk of death.

Animals seem to know which plants to feed on when in need of a physiological cleansing. It is not fully known how animals have acquired such information but it is assumed that this is a process that relies on causal associative learning. Isolated tribes seem to have gathered a substantial amount of knowledge about the health benefits of many plants, but the application of such remedies is usually accompanied by rituals, some of which may play a role in reinforcing the placebo effect.

Resource holding

Energy acquisition and sex are perhaps the strongest forces of nature that underpin life on Earth. Resources are all those items considered to be necessary for the survival of the individual and the species. The first consists of food, and with it territorial ownership where food can be harvested. In more recent stages of cultural evolution, any beliefs in line with behaviours which support survival are likely to be more readily embraced since they provide an adaptive benefit whether it is crucial for immediate survival or not; for example the conquest of territory may not represent an immediate benefit for survival, but it ensures the control of resources that are essential in the future. So beliefs that echo behaviours related to territoriality and home range are deeply rooted in our evolutionary past.

The second resource refers to sexual drive, which enables the continuity of the species. Beliefs that refer to sexual gratification are present in all cultures in apparently contradictory ways. While some cultures seem to celebrate the free expressions of sexuality, others impose moderation or abstinence. Although this might seem like a contradiction to our hypothesis that beliefs that align with nature are more easily embraced and resistant to eradication, this can be explained by an arms race approach between competing beliefs. In cultural settings where both natural drives (feeding and sex) are strictly regulated, such beliefs build on a sense of guilt which become very useful in controlling the populous through the means of religion. This is a strategy adopted by highly hierarchical societies where only the ones on the top are worthy of privileges. Comparing chimpanzee with bonobo societies there is also a relationship between hierarchies and sexual freedom.

The utility of beliefs is widely discussed under epistemic utility theory, a division of probabilistic philosophy. This theory proposes a decision making mechanism based on the probability of different outcomes of competing beliefs (Pettigrew, 2011). Coupling this approach with evolutionary theory and cognition supports the notion of a correlation between force of belief and expected utility.

Discussion

The word ‘belief’ is culturally perceived as religion, but this has hampered a more encompassing view of the biological mechanisms that regulate the formation of beliefs. Most of our daily decision making is built upon mundane and secular beliefs. This emphasis on religion has distorted the significance of biological processes regulating the adoption of religious beliefs and behaviours leading some authors to suggest that the embracing of religion and belief in God may have biological roots. The confusion relies on the difference between the belief in the meme and the biological mechanisms that support that belief.

Belief and Religious memes

The mystical memetic content of religious beliefs might have had its origin in the lower Palaeolithic (c.a. 40,000 BCE); the organised hierarchical religious structures are believed to have flourished during the Neolithic Revolution (c.a. 12,000-10,000 BCE) with the first agriculturalists.

Anthropologists have long assumed that a mental representation of mystical beliefs might have appeared around the same time as cave paintings. Since beliefs do not leave fossil record it is difficult to ascertain what our ancestors might have believed 50,000-40,000 years ago when they were painting those walls. Thus, toddlers show a tendency to scratch walls, even though they

do not yet hold any beliefs. The fact that the ancient people buried their dead is not necessarily a sign of religious beliefs either and it is possible that burial had a utilitarian end such as to avoid the unpleasant smell, flies and scavengers common to degrading bodies.

Religious beliefs and mythological narratives that survived to the present reflect an organisational structure akin to those of human societies, offering predictability, perceived truth and a sense of reliability and utility. Such beliefs are resistant to extinction even when they are challenged by evidence and rationality.

Religion is a particular form of magical thinking which includes a strong belief in a supernatural power that controls human destiny and explains causation and purpose through the intervention of superhuman agency. Alston (1967) listed specific factors that, when present in a sufficient degree, define a religion.

1 Belief in supernatural beings (gods and spirits).
2 A distinction between sacred and profane objects.
3 Ritual acts focused on sacred objects.
4 A moral code believed to be sanctioned by the gods.
5 Characteristically religious feelings (awe, sense of mystery, sense of guilt, adoration), which tend to be aroused in the presence of sacred objects and during the practice of ritual, and which are connected with the gods.
6 Prayer and other forms of communication with gods.
7 A world view or a general picture of the world as a whole and the place of the individual therein. This picture contains some specification of an overall purpose or point of the world and an indication of how the individual fits into it.
8 A more or less total organization of one's life based on the world view.
9 A social group bound together by the above.

All these items can be included in the four universal categories as follows; Intuitibility (agency 1,2,5); Predictability (3, 4, 6, 7,9); Reliability and Utility (7).

Evolution provided the brain with biological structures that support the formation of beliefs, but they cannot discriminate whether the belief is true or false. It is important to understand the difference between detecting information that may be deceptive and therefore unreliable and accepting information upheld as true or reliable.

Take as example the control as an important element for predictability; One of the most important characteristics of religions is that they satisfy the need to predict and control events (Spilka *et al*., 1985), but the need for control can be satisfied through means other than religion. A belief in human technological progress operates in a similar way (Rutjens *et al*., 2010). Belief in science and technology assumes we can control our environment and reduce uncertainty. For example, when driven by others in trains or flights, a belief in the technological advances behind such machines compensates for our lack of control over the situation, whereas the science of meteorology provides a degree of environmental predictability.

Predictability requires a cognitive appraisal of the future. Persons with high functioning autism (HFA) show an impairment in imagining mental travel into the future (Harris, 1991) and this has been proposed to explain why autistic individuals seem to be predisposed towards non-belief (atheism and agnosticism; Caldwell-Harris *et al*., 2011). This suggests that the concept of temporal predictability offered by many religions does not play a role in the formation of belief in autistic people. In autistic individuals, predictability is expressed in

terms of patterns expressed in routines, not as a foresight.

Belief and Non-Religious memes

Politics thrives on economic theories with a range of emphasis from competition to cooperation. While the first promotes resource-holding, and individual freedom, the latter concentrates on social justice based on the principle of fairness. Perhaps the most influential philosophers representing these approaches were Adam Smith (1723-1790) who illustrated how rational self-interest and competition can lead to economic prosperity, and Karl Marx (1818-1883) who developed the idea that human societies progress through class struggle: a conflict between an ownership class that controls production and a dispossessed labouring class that provides the labour for production. Although each of these approaches focuses on conflicting aspects of behaviour, nevertheless, they appeal to natural intuitions with long established evolutionary roots. Fierce adepts of each theory embrace their ideas in a quasi-dogmatic fashion, many of whom were willing to offer their lives for what they believed. Extreme instances of these theories align with the four characteristics discussed here.

Belief and Science

It is important to point out that the technological advancement of societies does not necessarily eradicate this need to satisfy the four traits of belief. As far as beliefs meet the need for "truth", they can be embraced independently of the feats of technology. This is because technology focuses more on the question "how" than "why". It is possible to build complex structures and machines to address *how* to solve practical problems. The purpose of technology is not to answer questions like "why are we here?"; "where do we come from?", "what is the purpose of my life?" The question "why" is underpinned by the formulation of theories that explain phenomena. These theories and the evidence that supports them can later be used for supporting technological development. But even in science there is a resistance to abandon well established beliefs. It is common among scientists to accept that when new evidence refutes a theory, it should be abandoned or reformulated in order to fit the new data. However, scientists are humans, subject to the hard-wiring of their biological brains, and an instinctive rejection of novel theories is pervasive among scientists. If the careful evaluation of new theories is necessary for the rigour of science, a closed mind plagued by excessive emotionally based scepticism does little for the progress of knowledge. Humans get emotionally attached to their beliefs as if they were agents impregnated with moral value. This emotional attachment hampers the progress of scientific knowledge through the rejection of theories that seem to fall out of all conventional knowledge.

Scientific beliefs are built on a pursuit of predictability, reliability and utility but the scientific method ensures that this quest should progress free of dogma or myths. The sense of predictability and reliability offered by particular beliefs provides utility in eliminating doubt. Faith in providence offers a false safety which removes any responsibility for the actions of the believer and follows the same mechanism as appeal to authority discussed above. Often this strategy requires less mental processing as it dispenses with any rational assessment of evidence.

Emotional attachment to beliefs

This paper attempts to offer an explanation to why some beliefs are so difficult to eradicate even though they seem totally

absurd when subject to rational appraisal. We suggested four classes of characteristics inherent to the meme itself which may trigger a degree of emotional attachment.

An attachment mechanism is operated by the release of neurotransmitters in areas of the brain that perceive reward. Any information that meets the expectations is thus perceived as reinforcement. Reward mechanisms are those which subject individuals to addictions, and thus the brain can become addicted to a rewarding belief in the same way it gets addicted to drugs.

Drugs have a direct effect on the action of neurotransmitters, but ideas and beliefs are abstractions, thus it is reasonable to ask: what biological mechanism triggers attachments to memes? The solution to this question should be pursued through research on the placebo effect and reward expectation. Studies in gambler psychology and reward expectation have suggested that it not the winning that creates the addiction, but the expectation of winning that drives the behaviour. An expectation is a non-consummated behaviour, but it is a powerful driver.

When beliefs meet the expectations defined in the four universal cognitive categories they are likely to trigger attachment mechanisms. The information perceived through words at the level of the cortex is then transduced into signals understood by the limbic systems in terms of evolutionary cost-benefit. Giving one's life for a belief is interpreted by the brain as reward expectation, since the pay-off in next life is believed to be higher than in the present circumstances. This is a game of reward expectation and we hypothesise that ideological fanaticism is a more readily embraced by individuals that have a neurobiological tendency for addictive behaviours.

An effective deceptive belief needs to pass through the cognitive filters that have evolved to detect deception and when it provides that "feeling of rightness" it is automatically protected by our mental processes because the memes composing the belief appeal to our intuition, offer predictability, and provide a sense of truth and reliability which is functional because it has utility. The beliefs avoid critical appraisal by appealing to the human natural tendency for cognitive bias in general and to confirmation bias in particular.

Conclusions

It is important to reiterate that natural selection does not select for the informational content of the beliefs, but it simply acts on the underlying cognitive processes. Thus the proposition that humans have a natural propensity to believe in God is as unlikely as having a natural propensity to believe in quantum physics. What is natural is the will to believe in something, no matter what, that feeds into the four cognitive domains suggested in this paper. One needs to be systematic and keep the study of belief as a separate discipline from the study of religion. Just as a specialist in building the foundations, plumbing and electric wiring of a house is not the same as the aesthetical creativity of the architect. In the same way that foundations can support a multitude of architectural designs, the neurobiological foundation of vertebrate brains can support a multitude of beliefs, such as religion, new age and political ideals. In this sense, religion is a *spandrel* of the evolution of the brain. It is a by-product of evolution rather than an adaptation. Note that the difference between an adaptation and a by-product is that whereas the first brings a survival advantage to its bearer the latter is just a consequence of a particular biological feature, such as obesity is not an adaptation, but a by-product of the evolutionary need

to accumulate fat as an energy resource for times of hunger.

Furthermore, taking into account that religion is such a recent phenomenon, evolution would have hardly any time to act on the human brain to turn religious commitment into an adaptive trait and therefore the focus of research should concentrate on the biology and evolution of cognitive processes that regulate belief.

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