Part 1

# Conceptual and psychological perspectives

Chapter 1

# A cognitive neuroscience of belief

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## Introduction

Belief is one of the most commonly used yet consistently unexplained aspects of contemporary cognitive neuroscience. Bertrand Russell claimed it was 'the central problem in the analysis of mind' (Russell, 1921, p. 231); however, few attempts have been made to explain the psychological or neural basis of belief itself. This continues to be the case despite the fact that beliefs forms a central part of our folk psychological explanations for behaviour. Unlike most other areas of cognitive science (e.g. attention, memory, perception, language, and action systems) cognitive neuroscience has typically neglected formal discussion of belief. This is due to several reasons, not least the nebulous and ill-defined nature of the construct. While free will appear to be less troublesome for current neuropsychology enquiry (Zhu, 2004), one might be forgiven for asking exactly what is so difficult about belief?

## Difficulties in conceptualizing the nature of belief

Agreement on a formal definition is one of the most hotly debated issues in contemporary philosophy and has obvious implications for any cognitive neuropsychological approach to belief.

The simple statement 'I believe that . . . ' belies a large number of possible interpretations of what is actually happening in the human brain when someone makes such a claim. One of the most remarkable things about belief is the ease and acceptance of such straight-forward statements in everyday life without. While the number of possible interpretations may cause surprisingly little distraction for the casual listener, it causes a great deal of consternation for the cognitive scientist who needs to define the processes involved to be able to understand how it may operate and be supported by the neural systems of the brain.

The issue at stake here, however, is not whether we find the concept of belief useful in everyday communication, but whether this everyday understanding of belief is valid such that it can be used for scientific investigation and, in particular, for those seeking to link the construct to selective cognitive process and their underlying neural states. The problem is more widely discussed among philosophers of mind (the philosophical study of the nature of the mental events) rather than cognitive scientists. Moreover, it is often difficult to make a clear distinction between questions of whether a neuropsychology of belief is possible, and what the likely nature of that belief might be. Although conceptually distinct, in practice, the latter tends to have considerable implications for the former. Baker (1987) identifies four major views on the 'correctness' of the everyday understanding of belief and how it may relate to underlying neural processes:

1 **Our common-sense understanding of belief is correct**. The common-sense view of belief (i.e. folk belief) tends to equate beliefs with explicitly held propositions. Here, such propositions are available as representations in memory and consulted when an appropriate situation arises. Among philosophers who have argued for beliefs as representations, Fodor (1975) is a particularly well-known exponent. Controversially, he has argued that a fundamental 'language of thought' – independent of the actual spoken language of the believer – underlies the representation of belief (and other mental states). A discussion of his 'language of thought' hypothesis is outside the scope of this chapter; however, this syntactic description of belief is not without its critics, and the strength of the passion it engenders can be seen from a repost by Still and Costall who went as far as to describe Fodor's theories as 'where one tries to keep a reasonably straight face while presenting the absurd consequences of the scheme as exciting theoretical revelations' (Still and Costall, 1991, p. 2).

The belief as representation' hypothesis, however, does not necessarily entail subscribing to an underlying language of thought. Both Armstrong (1973) and Dretske (1988) have argued that beliefs may be stored as semantic maps, an idea which seems a good deal less speculative now – in the light of recent advances in understanding how neural systems might encode even high-level information topographically or in multidimensional arrays (Lloyd, 2000, 2002) – than it may have seemed when first introduced.

2 **Our common-sense understanding of belief may not be entirely correct, but it is close enough to make some useful predictions**. This view argues that we will eventually reject the construct of belief as we now use it, but that there may be a correlation between what we take to be a belief when

someone says 'I believe that snow is white' and how a future theory of psychology will explain this behaviour. In a way, this is a 'missing link' argument which suggests that we talk about circumscribed beliefs and particular brain states, but are missing an important conceptual link which will change our understanding of how the two are connected and will cause us to rethink our model of belief (or even eliminate it). We can perhaps draw an analogy between how we now understand hemispatial neglect in terms of an attentional deficit to one side of space and how, through the ages, the same behaviour was undoubtedly explained as sensory loss. The traditional explanation may be no longer sustainable under rigorous scientific investigation, but some of the practical implications may be similar. Most notably, Stich (1983) has argued for this particular understanding of belief with his 'panglossian' approach.

3 **Our common-sense understanding of belief is entirely wrong and will be completely superseded by a radically different theory which will have no use for the concept of belief as we know it**. Known as eliminative materialism or eliminativism, this view, most notably proposed by Churchland (1981, 1999), argues that the concept of belief is like other old, obsolete theories, such as the four humours theory of medicine or the phlogiston theory of combustion. In these cases science has not provided us with a more detailed account of these theories, but completely rejected them as valid scientific concepts to be replaced by entirely different accounts. Churchland argues that our common-sense concept of belief is similar, in that, as we discover more about neuroscience and the brain, the inevitable conclusion will be to reject the belief hypothesis in its entirety. Although Churchland may make bleak reading for anyone wishing to retain the concept of belief in any sort of explanatory framework, one implication of this view is that our current concept of belief will be replaced by a number of better specified neuropsychological theories.

4 **Our common-sense understanding of belief is entirely wrong. However, treating people, animals, and even computers as if they had beliefs is often a successful and pragmatic strategy**. Dennett (1999) and Baker (1983) are both eliminativists in that they argue that beliefs are not adequately reducible to their neural underpinnings, but they do not go as far as rejecting the concept of belief as a predictive device. Baker (1983, p. 150) gives the example of playing a computer at chess. While few people would agree that the computer held beliefs, treating the computer as if it did (e.g. that the computer believes that taking the opposition's queen will give it a considerable advantage) is likely to be a successful and predictive strategy. In this understanding of belief, called 'interpretationism', or, in Dennett's terminology

taking the 'the intentional stance', belief-based explanations of mind and behaviour provide a convenient level of explanation and, while not ultimately reducible (unlike other cognitive constructs such as memory), could be of explanatory value in itself.

Others have similarly suggested that beliefs are best understood as 'dispositions to act' in a certain way in certain circumstances, and argue against the common-sense, representational view of belief, given the implausibility of its consequences. If you were asked 'do you believe tigers wear pink pyjamas?', you would say you do not, despite the fact that you may have never thought about this situation before. You are also likely to believe that there are fewer than three people in a duet, as well as believing that there are fewer than four people in a duet, fewer than five . . . and so on, *ad infinitum*. Proponents of the dispositional view of belief (such as Marcus, 1990) claim that such examples show that beliefs cannot simply be representations of 'facts' in the brain, as it would be impossible to have an infinite number of beliefs stored in finite neural structures. They claim that beliefs are therefore dispositional and only ascribable to observable behaviour in others.

Initially, this seems like a behaviourist approach to belief, and, unsurprisingly, was initially championed by philosophers such as Gilbert Ryle (1949), who were sympathetic to many of the goals of behaviourist psychology. Others (such as Schwitzgebel, 2002) have argued for a more liberal and less strictly behaviourist interpretation of the dispositional account, where dispositions could include non-observable behaviour and responses, such as emotional reactions or cognitive reorganization. This approach also suggests that our current conception of belief is realized as multiple neuropsychological systems.

## Are beliefs discrete entities?

The views expressed above can be thought of as discussions regarding the fundamental nature of belief and/or its dependency, or not, on neural systems. A further issue concerns whether it makes sense to conceive of beliefs (whatever their structure) as independent entities (i.e. circumscribed psychological units or cognitive systems), or whether beliefs only exist as coherent entities when conceptualized as part of a wider network of beliefs. The former position is known as atomism, the latter holism, and the distinction becomes clear when issues arise as to whether the same beliefs can be considered identical for any given referent. For example Price (1934, 1969), an atomist, conceived of beliefs as single propositions; so two people would be considered to hold the same belief if they both assent to the same belief sentence (e.g. 'snow is white'). Alternatively, proponents of the holist view (Davidson, 1973, 1984; Quine and Ullian, 1970) argued that beliefs can only be

understood in terms of their relation to other beliefs. For example if two people express the belief that 'snow is white' but one believes it is made of star-dust while the other believes it is frozen water, a holist would argue that they are not expressing the same belief, as they have radically different conceptions about the nature of snow.

This distinction is important for neuropsychologists, because it potentially defines the link between belief claims and how they relate to the underlying neuropsychological processes which support them. For example an atomist would expect that similar neural activation would occur for an identical task that relied on the same belief that *p*, regardless of whether additional beliefs relating to *p* are accepted or rejected over time. In contrast, a holist might expect brain activity to be radically different if and when new beliefs relating to *p* are acquired, as *p* can only be understood in the context of its interconnectedness with other beliefs. Therefore, a holist view is more likely to support a multifactorial neuropsychological account of belief, as multiple processes or multiple sites of neural activation might be involved by nature of the fact that then activation of any particular belief would involve the activation of related beliefs. This tradition might see belief as simply a linguistic label for a number of disparate cognitive processes, suggesting that the neural underpinnings of what we understand someone to be doing when they say 'I believe that . . . ' to be many and various and best explained as a complex system of more fundamental neuropsychological processes (Horgan and Woodward, 1985).

The dominant theme that arises from these philosophical perspectives is that there is unlikely to be a unitary belief formation process explained by a monolithic neuropsychological model. As such competing theories can be seen as making predictions about the likely neural involvement in belief processing, these can be compared with experimental data to provide evidence for the ongoing debate in the philosophy of mind. However, in the next section, the focus moves from philosophy of mind to consider how current clinical and theoretical based neuroscience approaches have contributed to understanding the nature of belief.

## Cognitive neuroscience approaches

Given that 'theories in the cognitive sciences are largely about the belief organisms have' (Fodor, 1981), one might expect considerable interest within the cognitive neuroscience community. The case for a neuropsychological basis for belief has received some debate in the neuroscience literature; however, most do not explicitly address beliefs as a discrete mental category but rather concern the relationship of mind to biological function. Moreover, most accounts do not distinguish between beliefs as a neurological phenomenon (based entirely on

the biology of the brain), and neuropsychological explanations, based on information-processing or functional approaches models of assumed underlying neural function. The paucity of studies reflect some of the problems outlined earlier regarding the philosophical nature and definition of belief.

Until recently the explicit study of beliefs has not attracted particular interest, with the exception of research into 'theory of mind' (the theorized ability to represent another person's beliefs and intentions). Indeed, 'theory of mind' ('mind reading') is often described in terms of belief (or false belief), yet it is not clear how explicitly current studies tackle the base construct. As Dennett (1978) has noted, in many instances predicting others' behaviour can be done without a 'theory of mind' and can be completed simply by observing the actual state of the world. Similarly, the relationship between the false belief task and 'theory of mind' is unclear, despite the fact that many studies conflate the two (Bloom and German, 2000), making 'theory of mind' research a potentially poor candidate on which to base any general theories of belief.

One novel and ingenious approach has been taken recently by Goel and Dolan (2003) who conducted an fMRI study using Evans, Handley, and Harper's (2001) belief-modulated reasoning paradigm. Evans' group found that syllogistic reasoning is impaired when the outcome of a problem is in conflict with an individual's belief, despite being correct in the context of the presented problem (e.g. no addictive things are inexpensive; some cigarettes are inexpensive; therefore some cigarettes are not addictive). Goel and Dolan compared brain activation between syllogisms where the correct answer was in agreement with the participants' beliefs, those that were belief discordant, and a condition using non-belief reasoning (e.g. all A are B; all B are C; therefore all A are C) to elicit activation specifically related to the effect of belief on reasoning. They reported left temporal activation for belief-based reasoning, and ventral medial prefrontal cortex activation when pre-existing beliefs caused reasoning to go awry, whereas successful suppression of belief for successful reasoning was associated with right lateral prefrontal activation. They concluded that belief-bias effects in reasoning may affect reasoning through emotional processing mechanisms known to involve the medial ventral prefrontal cortex, a conclusion not unrelated to much of Frijda's work on the links between emotion and belief (Frijda *et al.*, 2000).

While Goel and Dolan's study remains neutral with regard to a specific philosophical theory of belief (belief as representation, disposition, etc.), a study by Gallagher *et al.* (2002) specifically tackles belief by attempting to image the 'intentional stance' (Dennett, 1999) – the predictive strategy whereby we interpret the behaviour of another by assuming a rational agent whose behaviour is governed by intentional states. In this study, participants

were asked to play the game 'paper, scissors, stone' against an opponent whose responses were displayed on a computer screen. In one condition participants were told that they were playing against a human opponent, in the other the responses were randomly generated by a computer. In fact, in both conditions the responses were randomly generated, but when participants believed they were playing against a human there was significantly greater bilateral anterior paracingulate activation, which, the researchers suggest, shows a specific neural response for taking the 'intentional stance'. Although the findings of Gallagher *et al*. (2002) are of interest, it is not clear how useful they are for understanding the functional anatomy of beliefs unless one assumes that our ability to explain and predict other people's behaviour (i.e. 'theory of mind'), by attributing mental states and/or by taking an 'intentional stance', is operationally equivalent to adopting or holding a specific belief.

## Neuropsychological correlates of paranormal beliefs

One aspect of the study of beliefs that has attracted disproportionate attention is belief in the paranormal, not least because of its potential links with religion and psychosis (Persinger and Makarec, 1990; Peters, 2001). Paranormal belief has also been particularly linked to increased right hemisphere activation, and a reduction in left hemisphere dominance for language. Whilst Crow (1997) has controversially argued that this pattern is associated with the expression of frank psychosis and schizophrenia, it is certainly clear that this activation asymmetry is also associated with paranormal beliefs that are not accompanied by a psychiatric diagnosis. It has been reported that a belief in extra-sensory perception (ESP) in non-patients is associated with increased right hemisphere activation (Brugger *et al*., 1993a, 1993b), a finding which has also been replicated with measures of paranormal belief and neuropsychological measures such as of electroencephalography (EEG) (Pizagalli *et al*., 2000), olfactory discrimination (Mohr *et al*., 2001), and line bisection (Taylor *et al*., 2002).

Leonhard and Brugger (1998) argue that this lateralized pattern signifies over-reliance on right hemisphere processes, whose coarse rather than focused semantic processing may favour the emergence of 'loose' and 'uncommon' associations. They consider these effects lying on a continuum, whereby in some they contribute to novel thought and creativity and in other psychosis. However, it is unlikely that the degree of medically diagnosable 'illness' is a simple correlation with degree of hemispheric asymmetry, as many other factors (such as sociocultural factors, individual history, and coping styles) also contribute to such cognitive influences, beliefs and experiences being impairing, distressing, or disabling rather than considered as normal belief (Bentall, 2003).

Reports of hemispheric asymmetries and paranormal belief have also been described by Persinger (1983), who has amassed considerable converging evidence suggesting that right temporal lobe activity is associated with paranormal belief (the term 'paranormal' is used here in its widest sense, also to include religious and mystical beliefs). Persinger (1983) argues that mystical experience and religious beliefs are the normal consequence of transient activity in the tempero-limbic structures and has subsequently found that the strength of paranormal beliefs was positively correlated with the amount of activation in these structures. This correlation was found in individuals engaged in psychic studies (Persinger and Fisher, 1990), during specific episodes of glossolalia ('speak in tongues'), and transcendental meditation (Persinger, 1984) and with more general measure of paranormal experience (Persinger and Valliant, 1985).

The main implication of these neuropsychological findings is that widely-held religious, mystical, or paranormal beliefs are associated with specific patterns of cortical and subcortical activation. These can be studied by developing standardized psychometric questionnaires that can be the basis of drawing neuropsychological inference, as long as they are well validated by the appropriate application of cognitive neuroscience.

## Delusions as false beliefs

If the underlying cognitive (and by extension neural architecture) for belief and belief formation was organized as a modular system, then the study of brain injury (or the application of other module-friendly experimental methods) could provide (depending on location and combination) another production line of empirical investigation. The lesion method has proved to be a powerful tool for cognitive neuropsychologists in charting the potential relationship between mind and brain. Indeed, some forms of cognitive neuropsychology are only viable if the hypothetical modules envisaged in mind are both conceptually distinct in terms of the overall cognitive system and spatially distinct in terms of their putative anatomical location (Shallice, 1988). Brain injury may selectively damage cognitive modules, so their existence and function may be inferred from the experience, abilities, and behaviour of postinjury patients (Shallice, 1988).

Notwithstanding Fodor's prediction that beliefs, as highly elaborate knowledge systems, are the product of 'central' rather than modular processes (Fodor, 2000), there are useful parallels to be drawn between the successful and ongoing research into the executive system and attempts to understand the neuropsychology of belief (Bell *et al.*, 2003a). Drawing inspiration from

Burgess' (1997) analysis of methodology in executive function research, Bell *et al*. (2003) note that the executive system as currently understood fulfils many of Fodor's criteria for a 'central' process. Burgess argues that there is no direct 'process–behaviour correspondence', so that the executive system can only be seen to be working indirectly through the measurement of other cognitive processes with which it integrates. If belief is indeed a central process it may well operate in a similar manner and, as such, any attempts to find a single point of measurement (or single point of breakdown) would be inappropriate.

Given the caution Burgess points out with regard to employing and relying on single probes for complex interacting psychological constructs, it may seem strange that one avenue which has proved productive in the understanding of beliefs has been the study of delusions (i.e. 'pathologies of belief'). The recent application of a cognitive neuropsychology approaches to psychiatric symptoms (cognitive neuropsychiatry) attempts to better understand normal psychological function by studying psychopathology and by explaining psychiatric symptoms in terms of normal models of neuropsychological function (David and Halligan, 1996; Halligan and David, 2001). Early successes have produced specific and plausible mechanisms for how certain pathological beliefs might arise, most notably for the Capgras delusion (Breen *et al*., 2000; Ellis and Young, 1990; Ellis and Lewis, 2001; Hirstein and Ramachandran, 1997). In this account, damage to an unconscious face recognition pathway is impaired, leaving Capgras sufferers without the appropriate emotional response to familiar faces, potentially explaining why they may come to believe familiar people have been replaced by identical-looking impostors.

Unlike physical lesions or specific perceptual-based disturbances, delusions are not as easily quantified or defined. Despite being typically treated as pathological versions of normal belief formation, it has become increasingly clear that delusions are far more complex than originally represented in traditional psychiatry (Bell *et al*., 2003b; David, 1999).

Although it is by no means clear, converging methods currently employed by neuroscience could provide the conceptual glue that may eventually bind the physical and psychological levels of explanation with regard to the 'problem of belief'. The three approaches discussed above (functional neuroimaging, the lesion method, and examining neurophysiological and neuropsychological correlates of belief states) all provide valid approaches to the neuropsychology of belief. However, what is equally important is formulating a well-specified, conceptually constrained model to help guide and direct all three approaches.

## A model for belief formation

Belief formation is a complex process and, as already noted in the philosophy of mind literature, is likely to be supported by a number of processes. Bentall (1990) produced a simple conceptual cyclic model (Fig. 1.1) which seems to capture some intuitive aspects of belief formation; however, there are several reasons why this model is inadequate.

1 Philosophers and common sense argued that we do not choose our beliefs (review in Engels, 2002). For example we cannot decide to believe that it is snowing in Devon unless we have evidence that it is – or more obviously, disbelieve it is raining if we are getting rained on. This suggests that an adequate model of belief formation must involve both an explicitly unconscious component, as well as a process of conscious evaluation.

2 One aspect which seems particularly important is the role of the 'web of belief' in the belief formation process. This seems a necessary condition for beliefs to be meaningful, as well as an important process in the acceptance, rejection, assimilation, and integration of beliefs. Quine and Ullian (1970) noted beliefs must be integrated into our current web of belief, which may itself be changed (for example some beliefs may be mutually exclusive) as new beliefs are added. Indeed, the need to account for a 'web of beliefs' in belief formation processes has long been recognized. Davidson (1973, 1984) has been an influential proponent of the view that beliefs can only be understood by relating them to a background of other beliefs and desires; Fodor (1978) draws the conclusions from his 'language of thought' hypothesis that beliefs must necessarily be related to and justified by reference to other propositions. In social psychology, theories of belief networks are central to many theories on the psychology of attitudes (Eagly and Chaiken, 1993). Cognitive dissonance theory, as first proposed by Festinger (1957), has the discrepancy between active beliefs as eliciting a drive to make them coherent, and even many of the reinterpretations are essentially belief coherence models (Harman-Jones and Mills, 2002). Similarly, cognitive balance theory,

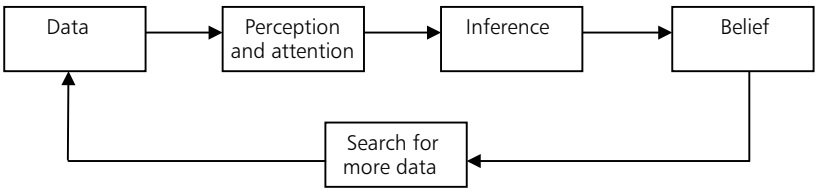


**Fig. 1.1** Bentall's (1990) 'back of an envelope' model of belief formation.

another foundational model in social psychology, has attitudes and beliefs as necessarily existing in relation to other attitudes (Heider, 1946; Abelson, 1986).

Indeed, even despite the relative paucity of neuropsychological models of belief formation, this integrative process is crucial. Stone and Young's (1997) strongly argue that belief formation involves weighing up explanations that are observationally adequate versus those that fit within a person's current belief set. 'Observationally adequate' could be interpreted here in a number of ways. For example work by Maio (2002) – who has studied the belief in social values such as freedom, equality and found that the number of reasons that people can produce to support their belief in social values (such as freedom and dignity) is typically less than other beliefs – suggesting that some important beliefs may not be so highly interconnected, or, at least, such connections are not always available to consciousness or easy to articulate.

3 This also suggests an important role for emotion in belief formation, a view which has not been without support. (Fridja *et al.*, 2000; Lance and Tanesini, 2002; Evans and Cruse, 2004). Social psychological research is now increasingly defining 'attitudes' in terms of both cognitive and affective components and propensities of individuals preferentially to favour these components in forming attitudes (Haddock and Zanna, 2000). Therefore, the influence of emotion on belief must be included in any complete model of belief formation.

4 Beliefs exist with differing degrees of confidence as to their likelihood or validity. A belief formation model should not simply 'output' a belief as having been accepted or rejected, but allow for a degree of conviction in the belief statement. Although there is reason to think that, ultimately, this may not break down into a simple, single dimension of belief (Harman, 1988, for example, has convincingly argued that, in some cases, people may be justified in having a higher degree of confidence in a proposition in which they do not believe than in a proposition that they do believe), a tacit acknowledgement that beliefs are not 'all-or-nothing' entities would seem to be essential to give any successful model of belief face validity.

5 Finally, beliefs may also formed on the basis of testimony rather than direct experience, a type of belief Rokeach (1968) called authority beliefs. An acceptable theory of belief must include the ability to hold these sort of 'second hand' beliefs, without direct perceptual experience of the subject of the belief.

## A candidate neuropsychological model of belief formation

While models of belief formation have been specified before in psychology, these have typically been created on a common-sense view of belief, without any regard to neuropsychological mechanisms which might support the process, or whether they are coherent in terms of their relation to supporting neurological structures. There is currently a paucity of explicitly neuropsychological models of belief formation, although a candidate model is reviewed below.

Possibly the most explicitly-specified model, derived from a cognitive neuropsychiatric analysis of delusions, is from Langdon and Coltheart (2000). As can be seen from Fig. 1.2, their model takes a three-stage approach: the first stage consists of monitoring processes that alert an individual to information in the environment, which may be novel or personally relevant. The second stage concerns the generation of hypotheses to explain any information that might be made salient by the earlier monitoring stage; with the final stage involving the evaluation of all possible explanations, a process by which the

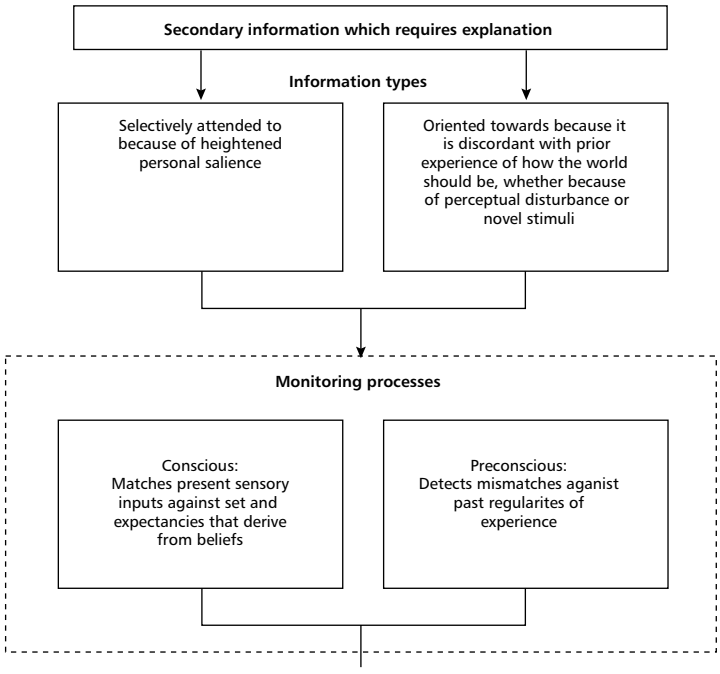


**Fig. 1.2** Langdon and Coltheart's (2000) neuropsychological model of belief formation. (Diagram by Bell, Halligan, and Ellis.)

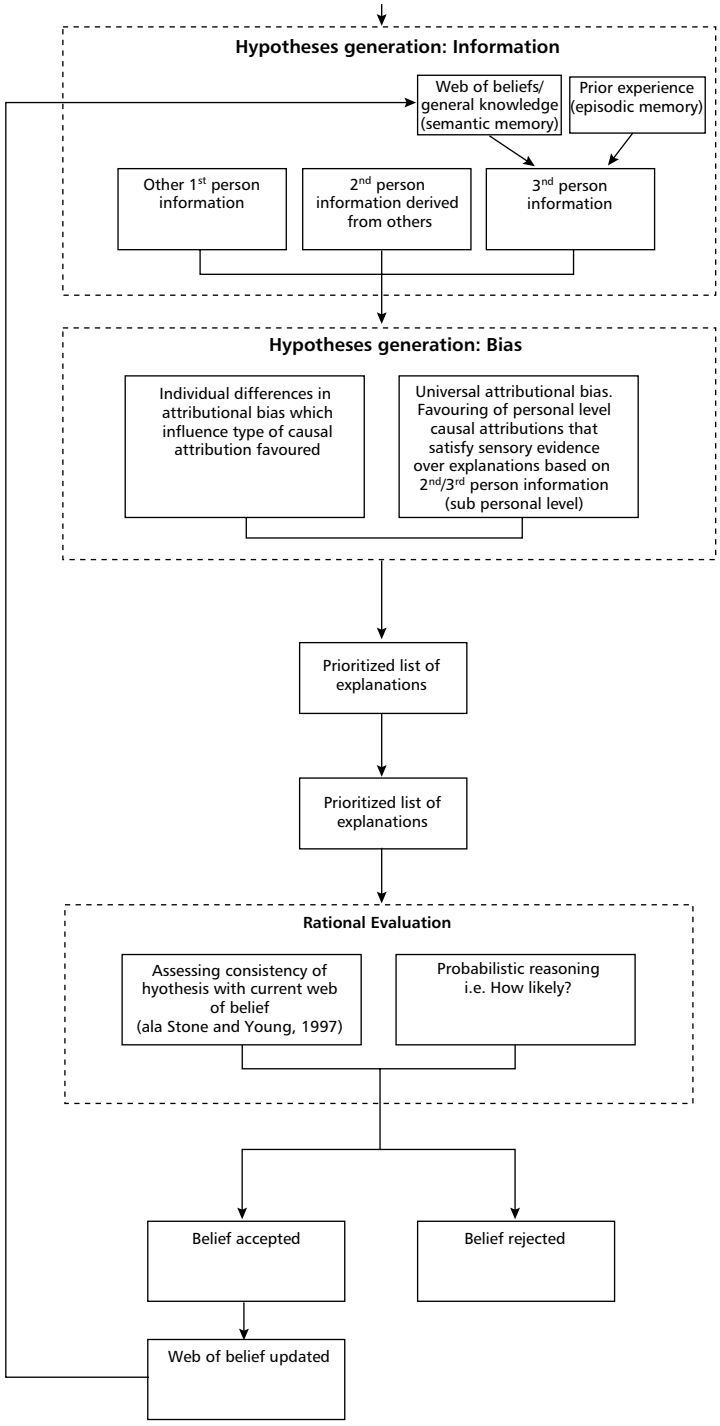
Hypotheses generation: Information
Web of beliefs/ general knowledge (semantic memory)
Prior experience (episodic memory)
Other 1st person information
2nd person information derived from others
3nd person information
Hypotheses generation: Bias
Individual differences in attributional bias which influence type of causal attribution favoured
Universal attributional bias. Favouring of personal level causal attributions that satisfy sensory evidence over explanations based on 2nd/3rd person information (sub personal level)
Prioritized list of explanations
Prioritized list of explanations
Rational Evaluation
Assessing consistency of hyothesis with current web of belief (ala Stone and Young, 1997)
Probabilistic reasoning i.e. How likely?
Belief accepted
Belief rejected
Web of belief updated

**Fig. 1.2** (*Cont.*)

most rational (or most likely) explanation is accepted as a belief. The monitoring stage acts as a filtering system to decide which sensory information is worthy of further consideration.

Langdon and Coltheart specify both a conscious and an unconscious component to this stage, including in their model a conscious monitoring process that matches sensory inputs against expectancies that derive from beliefs and an unconscious monitoring process that detects mismatches against past regularities of experience. Information that passes the presumed salience threshold might then cause the generation of hypotheses, which, in turn, may explain the experience. These hypotheses are drawn from a variety of information sources, including first-, second-, and third-person information, as well as episodic memory and a pre-existing 'web of beliefs' (drawing in part from semantic memory). It is at this stage that the hypotheses are weighted to enable a prioritized 'list' to be formed, the weightings being assigned by various sources of bias. Langdon and Coltheart argue that these may stem from either one of two sources. Their first source is universal influences (although we may be a little suspicious of the use of the term 'universal' here, and most people will probably be happier with the less grand 'sociocultural') such as the favouring of personal over subpersonal level explanations. The other is individual differences in attributional biases, such as those identified by Bentall *et al*. (1990) in pathological states (such as a tendency to blame negative events on others), or non-pathological biases that may occur in everyday life (Graham and Folkes, 1990; Mezulis *et al*., 2004). These hypotheses are then subjected to rational evaluation where both probabilistic reasoning and agreement with the current 'web of belief' is used either to accept the belief (and update the web) or to reject it.

Langdon and Coltheart's is a useful working model that covers most of the criteria referred to earlier for an adequate model. Some crucial processes however, particularly the use of the 'web of belief' to assimilate and test new beliefs, are left as theoretical black boxes. As discussed earlier, this may be an essential part of any model of belief; potentially both in terms of making a pretheoretical concept of belief coherent (as the holists would argue) and/or to capture the empirical data concerning the interconnectedness of beliefs and the influence of other beliefs on belief formation.

Similarly, perhaps we have to be a little generous in assuming that emotional effects on belief are adequately explained by the 'attributional biases' process of this model. Whilst affective factors almost certainly alter attribution, relying purely on the cognitive neuropsychiatric approach unduly dispenses with much good work done on normal belief in this area (see the aforementioned Frijda *et al*., 2000).

## Conclusions

One important conclusion from this comparison is that a cognitive neuropsychiatric approach to belief may lead to useful developments and testable theories. As the only explicitly neuropsychological model of belief of its type, Langdon and Coltheart's (2000) model is remarkably well specified, despite some notable ambiguities in their explanation of the operation of the component processes. However, these current models further suggest that the study of delusions, belief pathology, and even simply 'anomalous' belief is likely to be a useful and productive approach to understanding normal belief.

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