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Beliefs and the Brain

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'Facts do not penetrate into the world
where live our beliefs.'
Marcel Proust

While the ability to believe is an inherent feature of human thinking, it has virtually remained unstudied per se by modern neuroscience. A belief expresses mental acceptance of truth – the validity or reality of something – in the form of accepted adherence to a specific idea coexisting in a state of confidence and trust. Beliefs are so common in our lives that the term is often used synonymously with 'thought'. Variants include *dogmas*, i.e. beliefs that are so well established that they have lost their identity as such – leading to a de facto exclusion of non-believers – and *myths*, which correspond to a belief in the symbolic value of something which is known not to be real.

A belief serves the function of both representation (as of a concept) and justification (as for an act). Indeed, excluding the role of instinctive drives, without belief there is no action because there is no hope. Beliefs may become so intense that they pervade the being of an individual, as exemplified by religion and politics. While doubt tends to inhibit action, beliefs facilitate decision-making and subsequent acts, eliminating consideration of a wide range of solutions ('I know what I must do.'). In fact, beliefs only make sense with reference to doubt (i.e. the possibility that a belief can be challenged), a concept that was developed by Descartes and his 'cogito ergo sum' in the seventeenth century.

Beliefs are established on the basis of the integration and acceptance of outer and inner perceptions through our senses; they rest on four main types of proof demonstration: rational or inductive proof ('I believe in what I see.'); scientific (deductive or experimental) proof; custom (which may lead to progressive acceptance of novel ideas, art, etc.); and intuition and revelation (including faith, either religious or non-religious). In medicine, the placebo effect and faith-associated healing [1, 2] belong mainly to the last of these mechanisms, while *scientific beliefs*, which rest on reproducible experiments, belong to 'predictive thinking', where room for doubt is supposed to remain ('I believe that the sun will rise tomorrow morning, but I cannot be sure that this will happen.').

The realization that what were interpreted as scientific truths thirty or fifty years ago are now, in many cases, considered erroneous demonstrates the fragility of beliefs, even those seemingly supported by experimentation. In clinical research, randomized clinical trials are considered as the best examples of acquiring the most objective information on the efficacy of treatments. However, their interpretation does not escape the belief system and even constitutes good examples of scientific beliefs being introduced into medical practice, with two risks: the first is that their power of conviction is so strong that they transform into dogmas; the second is that they are not strong enough to counterbalance intuitive beliefs (either on the part of physicians or patients) in different, unproven treatments. By the way, the idea that experimentally established management is superior to intu-

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ition-derived treatment, and vice versa, also belongs to beliefs – not facts – even from the scientific point of view. These two options, after all, have never been compared to each other in clinical trials. This consideration also suggests that the most well-rounded physicians may not be those who refer to pure science only but those who are capable of considering the beliefs and intuitive wishes of their patients within the frame of the most recent acquisitions of science. This may constitute a good example of the fact that the coexistence of apparently antagonistic beliefs (here, evidence-based versus intuition-based medicine) may provide a safeguard to extreme shifts in one direction or the other.

Beliefs Are Patterns

'New' information that does not correspond to previous memories risks rejection because it challenges established experience and ways of thinking. Novelty tends to destabilize ongoing functioning because it introduces itself as an alien item for which no specific space is at hand. To be accepted, it must be transformed into familiar, 'comfortable' information, which comes to be considered reliable. In other words, new data must find their way into and place in existing patterns of thinking. This explains why revolutionary thinking is usually rejected as distressing and is not allowed to penetrate and modify (or destroy, like a virus would) pre-existing patterns of thought (including beliefs) – at least without struggle. In rare instances, however, the reverse may happen and previous patterns may be erased or dramatically transformed, sometimes corresponding to 'revelation', 'illumination' or 'conversion', whether religious or not. Newton's apple and the eureka phenomenon show that such extreme paradigm shifts occasionally happen in science. Newness is easier to integrate when fewer memories and patterns have been established, i.e. when the brain has not been 'empatterned' too much by repeated, organized stimuli. This lack of empatternment is a feature of young versus old brains, and popular thinking emphasizes this phenomenon in opposing the wisdom of old age in favour of the creativity of youth. Newness is accepted when there is no established pattern to match (i.e. the information is not 'new' to a reference which is precisely lacking) or when previous patterns can be inhibited. Creativity may indeed first need to incorporate a deconstruction process [3], which will avoid the limitations of reproducing mere variants based on empatterned mental scaffolding.

Emotional Reinforcement

Emotional valence differentiates beliefs from simple knowledge, as evidenced by emotional arousal when beliefs are challenged, either from outside (when personal views are opposed or denied by other persons) or from inside (when one is not telling what one believes or knows, as in a lie). Besides, a strong *feeling* that something is right is associated with eureka-like phenomena. Temporal lobe epilepsy and certain dreams provide a good example of this, with 'limbic storms' associated with feelings of truth or revelation. Beliefs can also lead to extreme states of well-being and satisfaction arising from thought and action, as one of the main features of beliefs is to render comfort when empatterned attitudes and positions are reinforced. Belief-associated emotions can be so strong as to justify the loss or sacrifice of one's own life or the lives of others for a specific belief, as shown only too well by fanaticism, whether in the context of love or hate.

Beliefs in Neurological Disease

Beliefs are the mainstay of the manifestations of many psychiatric disorders, but it is much less recognized that they play a significant role in other diseases. Altered beliefs are not uncommon in patients with brain lesions, including anosognosia and the denial of a particular dysfunction. These self-deception phenomena encompass Babinski's anosognosia for hemiplegia and denial of blindness in Von Monakow-Anton's syndrome [4], where confrontation with the deficit does not correct the denial but often invokes rationalizations to reinforce belief at the expense of reality [5]. Denial of memory impairment in Korsakoff syndrome and lack of awareness of language disturbance in Wernicke's aphasia are also spectacular examples of denial [6, 7]. Other types of neurologically induced beliefs are delusions associated with misidentification syndromes, as in the Capgras-Reboul-Lachaux syndrome, in which the subject is convinced that relatives have been replaced by nearly identical copies, who are impostors [8].

Explanations of altered beliefs in brain damage include confusion states, confabulation, disconnection, psychological reactions and impaired feedback [4, 6]. Feed-forward dysfunction may also play a role, as in the belief of the existence of an illusory third, non-paralyzed arm in certain patients with hemiplegia, when intentional expectations do not match actual perception of movement [9].

Ramachandran's [10] theory of the devil's advocate to explain anosognosia for hemiplegia in right hemisphere lesions deserves particular mention, since it emphasizes the specific role of the left hemisphere in the construction and maintenance of belief systems, with its attempt to keep stable our established models of functioning at all costs. In order to generate coherent action, the brain eliminates challenging information so that the perceived world fits into a known, stable, consistent system: 'all new information folds into our pre-existing worldview.' When something strange appears, the alternatives are either to ignore the information or to distort it in order to squeeze it into the empatterned framework. On the other hand, the right hemisphere, the 'devil's advocate', corresponds to an anomaly detector and a reality check to impose a change in perceptions when beliefs do not fit facts. The 'conservative' left hemisphere always tries to explain and rationalize, even when facing overt reality to the contrary, while the 'revolutionary' right hemisphere balances this phenomenon by easing, coaxing and sometimes brutally and abruptly forcing a change in the pattern to allow for the acceptance and absorption of new, heretofore unwanted, and unpleasantly perceived facts. When the right hemisphere is damaged, the impetus for balance is lost and the left hemisphere prevails to permit denial of the new information of left hemiplegia so that patterns of mental functioning remain stable, clinging to what they were prior to the hemiplegia.

None of these theories are entirely satisfactory, since exceptions can easily be found. It is likely that several mechanisms play a synergistic role in most of these pathological conditions.

Interestingly, 'nosognosia' [7] is a term that is not part of the established clinical vocabulary. It could be used to denote a phenomenon just the reverse of anosognosia, i.e. the acceptance of the perception of a disease. However, this term has been used to describe the belief that certain physical manifestations are symptoms of a disease (perhaps the neologism 'nosocredo' would be more appropriate). In neurological patients, symptoms which blossom from beliefs without a physical counterpart are not uncommonly found in parallel with a neurological disease, making the analysis and interpretation of reported symptoms much more clinically challenging.

Beliefs are also commonly present in the reasoning used by patients as they explain why they believe they have developed a particular disease, with psychological factors playing an especially prominent role [11, 12]. Indeed, more than one third of patients may believe that emotional factors are more important than medically relevant factors. Less than 15% of stroke patients spontaneously mention vascular risk factors (such as smoking or high blood pressure) as the underlying cause of their stroke [13], suggesting that beliefs and lack of awareness are intimately related.

Brain Correlates of Beliefs

While the above-mentioned examples from pathology suggest that brain function is critical for belief stability and the acceptance of change, they also show that no particular brain region can be considered as a privileged 'belief centre'. It is obvious that the frontal lobes play a major role in beliefs, since they regulate adhesion or opposition to information as well as subsequent executive behaviour. However, it is also striking that anosognosia in hemiplegia, one of the most spectacular forms of distorted beliefs, develops after posterior brain damage, while frontal lobes remain untouched. These distorted beliefs and their verbal expression as confabulations may be produced by brain areas which are disconnected from critical perceptual and storing processes (parietal and temporal lobes and circuitry) and from the frontally-based checking and inhibiting processes that can catch the initial error [14]. As for the brain mechanisms involved in creativity [15], 'global' brain functioning associating anatomically remote brain regions is likely for belief processing.

Of particular relevance here may be Mountcastle's hypothesis of similarity of function across the brain, based on the uniformity of the cortical structure. A common algorithm may exist throughout the cortex, enabling it to detect common hierarchical features of stimuli without accounting for the modality of the input [16]. Synesthesia is a good example of the overlap of different perceptions which may be associated with such a common algorithm. Considering beliefs, one may speculate that, when a stimulus falls outside of established patterns, it triggers unfamiliarity and unease, with a sense of 'chaos' which needs to be corrected in order to fit beliefs that are already in place.

Recent studies on sound perception – hinting tantalizingly at mechanisms of broader application that extend to beliefs – suggest that previously unheard, unpleasant sounds lead to neuronal 'agitation' with the subsequent release of dopamine to signal distress [17, 18]. By extrapolation, this understanding may apply not only to other sensory perceptions but also to inputs that fit or do not fit previously empatterned neural representations of established beliefs. This would correspond to a pattern-match-

ing selection process for incoming stimuli, amounting to a continual, interactive confrontation between actual perceptions and memories of past perceptions. Inferentially then, these acoustic studies, by exquisitely elucidating the physiological link between consonant and dissonant sounds and feelings and behaviour, provide a possible model to explain conflict – both in the narrow and the broader sense – arising from 'mere beliefs' as 'consonance' or 'dissonance' between established patterns of information and new information leading to emergent beliefs.

Beliefs appear to represent a critical junction between memories, expectations and executive behaviour [19], even though a physiological counterpart for their acquisition, stabilization, challenge, destruction and replacement remains conjectural. Even so, beliefs constitute an excellent example of the fact that, while escape from general rules of brain functioning (and 'hardwired behavior' [20]) is not possible, comprehending the role of beliefs as an intrinsic, physiological constituent of brain functioning overall advances our understanding of behaviours.

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