Rev. Neurosci., Vol. 23(3): 303–309, 2012 • Copyright © by Walter de Gruyter • Berlin • Boston. DOI 10.1515/revneuro-2012-0034

Processes of believing – a review and conceptual account

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Abstract

Processes of believing are thought to have an important impact on the control of human behavior. Recently, neuroimaging and neurophysiological studies have shown that believe processes involve brain areas known to be involved in emotion-related and cognitive processing. But there is a discrepancy between the increasing interest in empirical research and the lack of coherent terminology and conceptualization. We will show that in processes of believing, the medial frontal cortex plays a critical role within a widespread cortico-subcortical network owing to its role in valuation of internal and external events and in subjective control of action. Also, we will describe a model of processes of believing that integrates the divergent neurophysiological and conceptual aspects as a starting point for further interdisciplinary research questions.

Keywords: cognition; credition; emotion; functional imaging; medial frontal cortex; valuation.

Introduction

An anthropological perspective claims that belief systems, such as religion, can be found in all human civilizations (Nucholls, 2003). From this follows the assertion that humans are naturally inclined toward religious thoughts (Boyer, 2003). Although the specificity of religious beliefs appears to vary with sociocultural context, the prospect of a natural human inclination to religious thought would predict that there may be some cross-cultural cognitive similarities. On this approach, religious experience is considered as a state of physiological mental activity that is represented in the human brain (Boyer, 2003).

A critical aspect of belief processes is that they are thought to influence human behavior. Human behavior is guided by emotion-driven short-term goals and cognition-dependent long-term goals (Rolls, 2008). People reason upon different goals judging the potential reward associated with different options and the likelihood to achieve them. This valuation process reduces the complexity of a given situation to a probabilistic assumption about the subjectively most appealing goal. That is, internal states and external events are associated with subjective values, which are not absolute but relative given by the actual situation, the choice options, and the cultural context (Vogeley and Roepstorff, 2009; Vlaev et al., 2011). Notably, the reinforcement of predicted values can account for an enhancement of perceptual skills (Kahnt et al., 2011). Insofar as value functions can be modeled mathematically (Montague, 2007; Grabenhorst and Rolls, 2011), they typically result in subjective assumptions or beliefs about external events of the world. Conversely, beliefs play an important role, because they are facilitatory and inhibitory modulators to the truth value of logical conclusions (Goel and Dolan, 2003). On this background, we would argue that the subjective appraisal of the world and its driving forces is part of the processes, which commonly are ascribed to religious or secular beliefs. As was shown experimentally, the subjective appraisal of external stimuli has a direct effect on our actions influencing our attended as well as unintended choices (Tusche et al., 2010).

Here, we were interested to explore which brain areas have been found to be engaged in belief processes as evident from neuroimaging methods. Specifically, we were interested if the medial frontal cortex was involved in belief processes owing to its assumed role for signifying the salience of internal and external events, their subjective value, and the subjective control of action (Seeley et al., 2007; Nashev et al., 2008; Seitz et al., 2009). To address this question, we performed a search in Medline. We will show that the first studies focusing on the representations of belief processes in the human brain not only allow some initial tentative interpretations but also point to a lack of conceptual coherence. We will present a theoretical account that may be suited to bridge the different approaches to religious and secular belief processes from a neuropsychological perspective.

Methods

We searched PubMed (http://www.ncbi.nlm.nih.gov/pubmed/) for publications until January 12, 2012, using the search terms ‘belief, religious, neural correlates, mystical experience, religious experience, religiosity, and imaging’. Of a total of 156 papers, we identified those 11 studies that addressed the representation of belief processes in the brain of healthy subjects using imaging methods such as positron emission tomography and functional magnetic resonance imaging (fMRI) and statistical parametric mapping. Only brain regions with a significant signal change ($p<0.001$) corrected for limited spatial resolution as specified by the authors of the original articles were considered. The clusters were visualized by overlay of the mean coordinates of the cluster centers and the corresponding standard deviations onto the templates of the stereotactic space (Talairach and

Tournoux, 1988) as described elsewhere (Seitz et al., 2006). For those studies using the Montreal Neurological Institute brain as template, a linear transformation algorithm was used (Brett et al., 2002).

Results

The eleven publications showed a widespread network of cortical and subcortical activations including the medial and lateral frontal cortex, the precuneus in the parietal lobe, the temporoparietal junction, the cingulate, and the cerebellum. Each of the studies shows an involvement of the medial frontal, which could be clustered into three groups (Figure 1). The first imaging study addressing the issue of which brain areas are involved in relation to belief processes was the study by Azari et al. (2001). These authors showed that Christian subjects achieved and sustained a Christian religious state during memorizing and reciting the 23rd psalm showing a trend toward decreased negative affect. This was accompanied by further activation areas involved in memory and visual imagery processes such as the dorsolateral frontal cortex, the right precuneus, the cerebellum, and most prominently, the medial dorsal frontal cortex. Later, the critical role of the dorsal medial frontal cortex was substantiated also by a network analysis approach (Azari et al., 2005).

Beauregard and Paquette (2006) reported that mystical experience in nuns activated several brain areas throughout the brain including the ventral medial frontal cortex and subcortical structures (Figure 1). Shortly later, it was found that the anteromedial prefrontal cortex was activated when subjects made implicit associations involving consistent gender and racial stereotypes (Knutson et al., 2007). Han et al. (2008) showed that personal trait judgments regarding the self or public persons showed significantly greater activity of the mid-dorsal medial frontal cortex in Christian than in non-religious subjects. Moreover, it was reported that religious participants recruited brain areas during personal prayer that had been implicated in social cognition such as the medial dorsal frontal cortex, the precuneus, and the temporoparietal junction (Schjoedt et al., 2009). This is of note because there is a considerable neuroanatomical intersubject variability concerning the brain areas activated in relation to religiosity (Kapogiannis et al., 2009). Nevertheless, in a study in which subjects were requested to judge statements about religious belief, fMRI showed activity in a widespread network of cortical including the ventral medial frontal cortex (Kapogiannis et al., 2009).

There are also a few studies addressing the brain areas engaged in secular beliefs (Figure 1). For example, false beliefs were reported to induce greater activation of the dorsal anterior cingulate close to the mid-dorsal medial frontal cortex than true beliefs (Sommer et al., 2007). This was true in children aged 10–12 years as well as adults, whereas the posterior cingulate and the right rostral prefrontal cortex were activated in children but not in adults (Sommer et al., 2010). The behavioral relevance of these observations became apparent from the partial overlap of brain areas engaged in false belief reasoning and inhibitory control of action as shown in adults (Rothmayr et al., 2011). In addition, it was found that beliefs are updated by accumulating different pieces of information when a decision has to be made. Increased uncertainty during such an evidence accumulation was associated with activity at the transition zone of the anterior cingulate to the medial frontal cortex, whereas greater underconfidence was related to activity in mid-dorsal medial prefrontal cortex (Harris et al., 2008; Stern et al., 2010). Interestingly, the dorsal medial frontal cortex was shown to be active when Christian subjects were engaged in religious thinking (Harris et al., 2009).

Discussion

Meta-analysis

We have shown that in the PubMed database of the National Institute of Health, there are only few neuroimaging studies addressing the issue of which brain areas become engaged in relation to religious and secular belief processes. There is a great trust in neuroimaging methods because they provide a robust though indirect account of the complex neural activity in the working brain (Magri et al., 2012). Although research on belief processes obviously is only in its infancy,

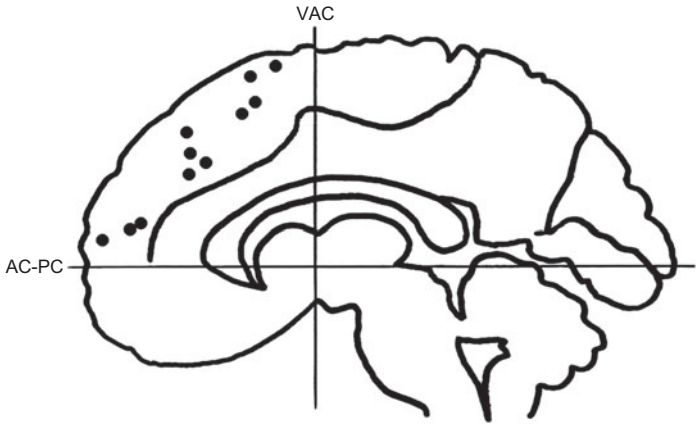

Figure 1 Activation areas in the medial frontal cortex related to processes of believing mapped into the stereotactic space of Talairach and Tournoux (1988). AC-PC, line through the anterior commissure and posterior commissure; VAC, vertical plane through the anterior commissure.

the cortex at the medial surface of the human brain extending from the anterior cingulate to the medial frontal cortex was commonly found in these studies. The three studies investigating religious experience showed activations in the dorsal medial frontal cortex (Table 1). The other studies on belief reasoning and uncertain judgments involved the middorsal portion of the medial frontal cortex, whereas mystical experiences involved the ventral anterior medial frontal cortex. These results are corroborated by recent event-related potential studies, which reported as well that belief and desire involve medial frontal areas (Liu et al., 2009). It is interesting that serotonin levels were found to correlate inversely with spiritual experience (Borg et al., 2003). In contrast, the modulatory effect of affective processing on reasoning activated the ventral medial frontal cortex below the intercommissural line (Goel and Dolan, 2003).

It is of note that the work of well-known researchers such as Richard Davidson, Andrew Newberg, or Vilayanur Ramachandran was not captured in our search. A specific search for Vilayanur Ramachandran who forwarded the idea of a religious module in the temporal lobe (Ramachandran et al., 1997) disclosed no single publication in PubMed addressing processes of religious or secular belief. Newberg et al. (2001, 2010) chose to list their publications under the search term of meditation. Interestingly, these authors observed apart from task-related activations in the cingulate cortex, dorsolateral prefrontal cortex, orbitofrontal cortex, precuneus, thalamus, and cerebellum also an involvement of the medial frontal cortex. Note also the partial overlap with activation areas found in compassion and nonreligious meditation (Lazar et al., 2000; Lutz et al., 2008). Even at rest, the anterior part of the medial frontal cortex was more active in long-term meditators as compared with new meditators, suggesting a tuning of brain function by the experience of meditation (Newberg et al., 2010).

Lack in conceptual coherence

Our findings based on search terms such as belief, religious, neural correlates, mystical experience, religious experience, and religiosity point to an obvious deficiency in conceptual coherence. Meditation, for instance, is a spiritual activity that often is practiced in the context of religions and is supposed to lead to an enhanced state of consciousness. However, these mental processes are bound to traditional cultural origins, are ill-defined operationally, and are often used interchangeably. In particular, there is a difference whether one practices a Christian, a Buddhist, or a secular type of meditation, which all are related to differences in the development of religious attachments (Kirkpatrick, 2005; Granqvist, 2010). Furthermore, there are differences between secular and religious processes of believing, although in both, one can find reference to the concept of trust, a neurophysiological entity that was shown to be modulated by the neuroendocrine hormone oxytocin (Kosfeld, 2005; Neumann, 2008). With regard to Christian religious experiences, one can refer to the concepts forgiveness and compassion (Davis, 2001; Farrow et al., 2001). Hence, there is a close link to empathy (Preston and de Waal, 2002). Both religious experience and empathy as mental activities include the valuation of events involving the dorsal medial frontal cortex (Seitz et al., 2006). This valuation function corresponds to the Gestaltkreis concept by von Weizsäcker (Schott, 1981) who introduced the valence of sought experience as basis for conscious perception of the subject. Self-explanation of thoughts is closely related to the subjective perspective on internal mental activity and external events (Wegner, 2005). Thus, the subjective perspective most likely is a probabilistic account closely related to subjective belief processes.

Therefore, we submit our view that there is a need of an integrative and interdisciplinary approach to define belief processes such that theoretical conceptions can be aligned with neurophysiological concepts that can be objects of empirical research.

Theoretical considerations of belief processes

In this section, we present a theoretical account that may bridge the different conceptual and empirical approaches to religious and secular belief processes from a neuropsychological perspective.

Table 1 Activations in the medial frontal cortex related to processes of believing.

Authors	Task	Stereotactic coordinates (mm)		
		x	y	z
Azari et al. (2001)	Psalm recital and memorizing	7	10	68
Sommer et al. (2007)	False belief	-8	16	46
Harris et al. (2009)	Evaluation of religious statements	12	16	64
Schjoedt et al. (2009)	Personal prayer in religious subjects	8	20	50
Han et al. (2008)	Christian self-judgment	8	27	35
Sommer et al. (2010)	False belief attribution	4	34	40
Stern et al. (2010)	Greater uncertainty in sampling	6	33	30
Rothmayr et al. (2011)	Belief reasoning+inhibitory control	10	36	44
Beauregard and Paquette (2006)	Mystical experience	-11	52	13
Knutson et al. (2007)	Combined race and gender associations	20	51	9
Kapogiannis et al. (2009)	God's perceived involvement	9	66	6

For the 'process of believing' as it might appear in a religious or secular manner, we would like to coin the neologism 'credition'. Credition is conceived as a psychological term in analogy to emotion and cognition that denotes the mental activity related to what we call 'he/she believes' (Angel, 2006, 2012). Most likely, belief processes differ with respect to the object, the intensity, and the subjective expression of believing. The concept of creditions focuses explicitly on the process character, that is, on what happens when someone is believing. Creditions are constituted by cognitive processes such as subjective perspective taking, valuation of internal states and external events, perceptive reinforcement learning, and selection and preparation of action. In fact, creditions are conceptualized as nonreflexive mental processes at the interface between perception, attitude, and action. Notably, this concept is not exclusive to the notion that not all processes of believing reach consciousness (Teske, 2007). The relation of creditions and attitudes is reciprocal, because the processes of believing build the basis for attitudes, but conversely, attitudes modulate the processes of believing via the subjective valuation of new experiences. Attitudes, on the other hand, heavily influence our actions and the selection of actions.

Creditions are proposed to be characterized by four largely interdependent bio-psychological functions. First, there is the cognitive process of reducing the complexity of our internal and external perceptions (Palmeri and Cottrell, 2010) to a simplified subjective perspective. This unconscious selection function constitutes our attitudes or mind sets concerning ideas, knowledge, values, or even moral claims that nevertheless are subjectively experienced as comprehensive. Second, creditions convert the attitudes or mind sets into supposed appropriate (re-)actions. This preparation process is interdependent with several systems, as for instance, the predictive system that provides the individual with information about the feasibility of deployable actions and, in consequence, modulates the preparation of actions (Delevoye-Turrell et al., 2010). The number of potential choices will be reduced during this conversion process, which finally prepares a 'relevant space of action'. This mental process is instrumental for abbreviating the time of decision-making. Third, attitudes and mindsets are stabilized by the experience of reward for the subject, which continuously acts in the social environment. Fourth, creditions are modulated by stored memories and the cognitive and/or emotional development as well as by the physical body including physical health, psychic integrity (Koenig, 2002), and sexual arousal. Most likely, creditions can be influenced by pharmacological as well as illicit drugs because they induce hallucinations and misperceptions.

Notably, there is a fine tuning between the processes stabilizing a subjective perspective and new experiences modifying the subjective perspective. Thus, creditions typically induce a positive and self-assuring feeling. Ultimately, they lead to habits and rituals. Potent agents stabilizing and modulating the formation of creditions are rewards and expected values. Thus, creditions stand in a finely tuned balance also with emotions. External rewards can be achieved by appropriate actions. The likelihood to act appropriately can be enhanced by adequate cognitive or emotional perspective taking, which has also been labeled as mentalizing or empathic processing (Preston and de Waal, 2002; Frith and Frith, 2003). In addition, creditions are also influenced by internal states related to physical conditions and emotional states. One could argue that creditions generate a cognitive space of subjective memories, introspection, and expectation of reward (positive change of affect) in the sense of a learning process. Because creditions are purely mental processes, they will follow their specific courses independently from influences from the outside, which nevertheless will influence the contents of these processes. It is tempting to speculate that this kind of learning is not specific for religious beliefs but might in a comparable way also occur in secular belief processes, faiths, or in political or even economical convictions.

Neurophysiological basis of belief processes

Recent neuroimaging and neurophysiological evidence suggest that the model of creditions may be justifiable from a neurophysiological point of view in as much as cerebral processes intimately connected to the concept of creditions involve the medial frontal cortex. Specifically, cognition-based perspective taking and emotion-based perspective taking engage different closely adjacent, but functionally different nodes within large-scale cerebral circuits involving the medial frontal cortex (van Overwalle, 2009, 2011). These large-scale cerebral circuits that have been described initially in neuroimaging data obtained at rest (Seitz and Roland, 1992; Raichle et al., 2001) have been shown later to signify the salience of internal and external events and their subjective value (Seeley et al., 2007; Seitz et al., 2009). The ventral medial frontal cortex computes the expected value, reward outcome, and experienced pleasure for different stimuli on a common value scale (Grabenhorst and Rolls, 2011). The anterior medial frontal cortex encodes stable representations related to the subjective perspective of social events, abstract categories, person concepts, and self-schemata (Krueger et al., 2009; Seitz et al., 2009; Caspers et al., 2011). When it comes to behavioral decisions, the medial frontal cortex becomes engaged in a differential manner. For example, intuitive judgments that occur without explicit verbal awareness were reported to be related to enhanced activity in the medial orbitofrontal cortex, the anterior cingulate, and the anterior insula (Volz and von Cramon, 2006; Kuo et al., 2009). Furthermore, the ventral anterior and dorsal medial frontal cortices are functionally related but mediate different aspects of control of behavior. Accordingly, activity increased in the dorsal anterior cingulate close to the medial frontal cortex and decreased in the orbitofrontal cortex when a selected response followed the participants' decision during monitoring of their behavior (Walton et al., 2004). Specifically, the posterior medial frontal cortex is engaged in initiating appropriate compensatory actions when a goal is missed and in predicting posterror adaptations (Ullsperger et al., 2007; Danielmeier et al., 2011). Notably, differences in activation as well as in gray matter density of this region have been found to explain individual performance differences of action selection (Schlaug et al., 1994; van Gaal et al., 2008). Animal experiments have shown that neurons in the medial frontal cortex exhibit complex discharge

characteristics most likely reflecting decision values (Kennerley and Wallis, 2009; Luk and Wallis, 2009). Convergence evidence comes from lesion studies in humans that showed that damage to the medial dorsal frontal cortex impairs cognitive perspective taking (Shamay-Tsoory et al., 2009). Moreover, there is a double dissociation of orbitofrontal damage disrupting choices as compared with lesions of the dorsal medial frontal cortex disrupting the generation of action values (Camille et al., 2011). The medial frontal cortex is part of the extended circuits with functional connectivity to the posterior temporal sulcus, the temporoparietal junction, the anterior temporal cortex, and the basal ganglia and thalamus (Seitz et al., 2011) entertaining a prominent development from adolescence to adulthood (Burnett and Blakemore, 2009). Therefore, the frontal cortex provides a top-down modulation of sensory cortices (Gazzaley et al., 2005; Hunter et al., 2010), which is functionally abnormal in patients with schizophrenia (Bassett and Bullmore, 2009) and severely disrupted in the chronic vegetative state (Boly et al., 2011). Thus, many components of the brain structures relevant for belief processes have recently been identified. But many more neuroimaging and electrophysiological studies to come will enhance our knowledge about the representations of belief processes in the human brain.

Conclusions

We propose here that the subjective appraisal of internal states and external events is tightly related to secular or religious belief. We have outlined that belief processes, which we call creditions, represent a largely neglected but nevertheless fundamental principle of human brain functions, which is critically related to the integrity of the medial frontal cortex.

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Received March 12, 2012; accepted March 21, 2012; previously published online May 3, 2012

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